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YUKON RIVER DAILY HYDROLOGIC FLOW MODEL

YUKON RIVER BASIN STUDY

This project was completed for the Yukon River Basin Study, an intergovernmental study funded by the governments of Canada, Yukon and British Columbia.

YUKON RIVER BASIN STUDY
HYDROLOGY REPORT NUMBER 3

MARCH 1984

Inland Waters Directorate
Pacific and Yukon Region
Vancouver, B.C.

YUKON RIVER BASIN COMMITTEE

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This report was funded by the Yukon River Basin Committee under the terms of "An Agreement Respecting Studies and Planning of Water Resources in the Yukon River Basin" between Canada, British Columbia and Yukon. The views, conclusions and recommendations are those of the author and not necessarily those of the Yukon River Basin Committee, or the Governments of Canada, British Columbia and Yukon.

ABSTRACT

This report describes the results of Project #44, "Daily Hydrologic Flow Model" of the Yukon River Basin Study, carried out jointly by Canada, Yukon and British Columbia. The report is a guide to the use of a hydrologic flow routing model for the Yukon River in Canada that computes downstream effects on river discharges and elevations resulting from operation of existing or proposed water resources projects upstream. The model simulates these effects using mean daily discharges in the SIMPAK computer program. Further detailed information regarding the SIMPAK program is available from the Inland Waters Directorate.

The first three chapters of the report introduce readers to the SIMPAK program by describing its capabilities, its usual configurations and modes of operation. Descriptions of procedures to set up and revise a model are also provided. The remaining chapters each describe a portion of the basin model and provide relevant information reguired to run the model.

Also included as appendices are descriptions of field surveys in the headwater lakes portion of the basin. The data obtained from the surveys will be useful in refining the Marsh, Tagish and Bennett Lakes portion of the model.

RESUME

Sont décrits les résultats du programme n^{o} 44 sur le modèle hydrologique de l'écoulement journalier, qui a été réalisé conjointement par les gouvernements du Canada, du Yukon et de la Colombie-Britannique dans le cadre de l'Etude du bassin du fleuve Yukon. Est démontrée l'utilisation d'un modèle du cheminement de l'écoulement pour la partie canadienne du fleuve, qui permet de calculer les effets sur le débit et le niveau des eaux en aval d'aménagements actuels ou proposés touchant les ressources en eau en amont. Les effets sont simulés à partir des débits journaliers moyens à l'aide du programme SIMPAK. Des informations plus détaillées sur ce programme peuvent être obtenues de la Direction générale des eaux intérieures.

Dans les trois premiers chapitres, on introduit le lecteur au programme SIMPAK en décrivant ses possibilités, les configurations habituelles et les façons de l'utiliser. On décrit également la façon d'établir et de réviser un modèle. Les autres chapitres traitent chacun d'une partie du modèle et présentent des informations nécessaires à son utilisation.

Des relevés sur le terrain dans la zone des lacs d'amont sont expliqués dans les annexes. Les données produites par les relevés serviront à perfectionner la partie des lacs Marsh, Tagish et Bennett du modèle.

ACKNOWLEDGEMENTS

This report was prepared by the staff of the Water Planning and Management Branch, Inland Waters Directorate, Pacific and Yukon Region. Mr. J.C.Y. Lee, under the direction of Mr. R.O. Lyons, was responsible for the preparation of the report. The SIMPAK computer program described in this report was developed previously by the Water Planning and Management Branch. Assistance was provided by Mr. N.E. Dalley on computer system applications, Mr. M.I. Payne and Ms. M.P. Clark on hydrometric data preparation. Mr. R.N. Boak and Ms. M.P. Clark were responsible for the preparation of all figures shown in this report. The report was typed by the staff of the Word Processing Unit, Inland Waters Directorate. Much of the description of the SIMPAK program in this report was first presented in Supplement 8 of the Mackenzie River Basin Study Report of 1981.

Computerized hydrometric data for the Canadian portion of the Yukon River Basin was provided by the Water Resources Branch, Inland Waters Directorate. Cooperation was received from U.S.G.S. offices in Anchorage, Alaska and Reston, Virginia in providing hydrometric data for relevant stations in Alaska.

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CHAPTER 1
INTRODUCTION

The Yukon Basin Model is a mathematical model of the main tributaries of the Yukon River. It is operated by an electronic computer using the computer program SIMPAK. Recorded mean-daily discharges and water elevations at key points in the basin are required as input data to define the hydrology of the system. Using this model, the effects of any changes in flow at an upstream point on the river can be estimated for any downstream location.

This type of model is termed a "daily routing model" because it simulates the flow-routing effect of the river channels and lakes upon the downstream movement of water through the river system. It handles the river flows as a series of mean-daily discharges, one value per day, for each station in the model. All flow calculations are based upon those daily discharges.

The routing model provides a tool to analyze the changes that a water resource development could cause to the hydrologic system. Knowing the operating characteristics of the proposed development and the basic hydrometric data along the river, the model can simulate the hydrologic conditions that would occur if the development were in existence. This is done by routing the simulated flows from the project site, along with the natural flows that enter the river downstream, to compute simulated flows for any downstream point along the river.

The model covers only the major tributaries of the Yukon River system and generally does not go upstream of any presently existing or proposed water resource developments. Additional tributaries can be added as necessary. For any test, tributaries not needed can be dropped.

The model consists of three separate segments (Figure 1.1) that are pieced together as necessary to route flows downstream through the system. The three segments are:

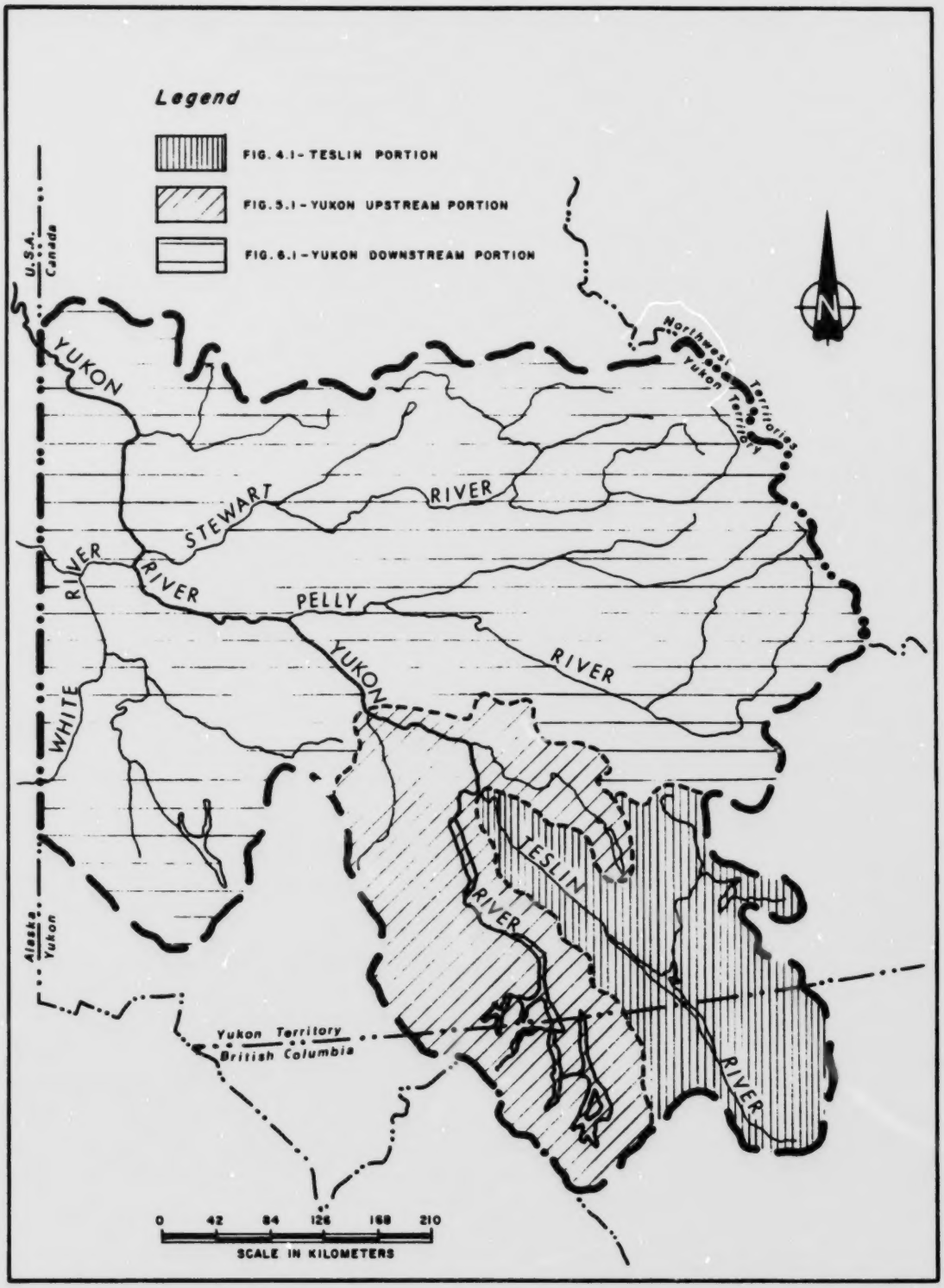


FIGURE 1.1: Key Map of Yukon River Basin in Canada

a) Teslin Lake to Telsin River at the mouth
b) Yukon Headwater Lakes to Yukon River at Carmacks (excluding Teslin River)
c) Yukon River at Carmacks to Yukon River at Eagle, Alaska (including Pelly River, White River and Stewart River).

All of these segments are modelled by the SIMPAK computer program. They all require recorded mean-daily discharges as input. Stage-discharge relationships are required wherever water elevations are computed and storage-elevation relationships are required for all lakes and reservoirs. The operating rules or operating discharges for any reservoir or similar water resource development being tested are also necessary input to the model.

This report describes the SIMPAK computer program and how it is used to model the Yukon River system. The discussion of the program describes the flow routing procedures used by the program and describes how input data is formulated to define the model. The several portions of the model are discussed separately in Chapters 4 through 6. In these discussions values for all parameters that define the characteristics of the river are provided.

Similar SIMPAK models have been prepared by Inland Waters Directorate for other river basins in Canada. Some of these are the Fraser River, the Columbia River in Canada, and the Mackenzie River system. Under the Mackenzie River Basin Study of 1981, an extensive SIMPAK model of the Mackenzie system was reported in "Supplement 8" of the Mackenzie River Basin Study Report. This report has been patterned after Supplement 8 and has used descriptions of the SIMPAK program that were presented in that report.

The detailed operating instructions for the SIMPAK program are provided in the SIMPAK User's Manual.

CHAPTER 2
SIMPAK PROGRAM DESCRIPTION

The SIMPAK program is a package of computer subroutines that undertake various modelling operations on streamflow data. The program is intended for studies of river regulation and control, i.e. to compute the detailed changes in the flow regime due to upstream reservoirs or diversions. By linking together several computations or "operations" which each modify one or more series of mean-daily discharge records, the flow in a river can be simulated.

For those not familiar with stream flow modelling, a short description of the process of a routing model will be useful. Basically, a streamflow routing model consists of several "nodes" passing data from one to the other. Each node represents some physical or functional operation, either by providing data to the computer from an input device, or by doing some calculations using data already stored in the computer. Some of the nodes simply represent measured streamflow records, usually a time-series of average daily streamflow values. Others take the data from two or more specified nodes and combine them in some manner. The most significant nodes are those that do some sort of operation on the data to simulate a physical process in the river. Thus, a typical streamflow routing model describes a river system as a series of nodes functionally tied together by the transmission of data from one to the other. A model may be easily conceptualized and described in a schematic diagram such as the example shown in Figures 2.1 and 2.2.

The SIMPAK program is simply a convenient tool to keep track of the time-series data at each node, to pass the data from one node to another and to carry out specified operations on the data at any node. The standard operations of the program treat the data as specific streamflow information, however, the program user may produce additional operations to treat the data in the nodes as any desired time-series.

SIMPAK was developed by the Inland Waters Directorate (IWD), Pacific and

Yukon Region, as part of its participation in the joint federal provincial Fraser River Upstream Storage Studies. The program was patterned after the U.S. Corps of Engineers' SSARR model, a program much more powerful but also much more complex and time consuming than SIMPAK. Initially, the river routing and reservoir regulation functions of the SSARR program were built into a separate program framework to make up the SIMPAK program. Subsequently, several other functions were added. Through various updates, the program has evolved into its present form.

2.1 Features of SIMPAK

The SIMPAK program is written in the FORTRAN IV language, with some of the auxiliary input/output and data handling subroutines written in the ASSEMBLER language. The program is intended for use on a large computer system, although it has been run successfully on some medium sized systems.

SIMPAK consists of a framework that reads the input data, including the model instructions, sets up the logistics of the computer operations and controls the sequenced operation of the many separate program modules that perform the individual modelling operations. This modular structure makes it much easier for the user to alter the program if desired; parts can be easily added or removed with a minimal knowledge of the program.

The program consists of a number of separate "operations", each programmed within separate subroutines. Each of these operations does some manipulation or hydrologic computation that simulates the behaviour of the river system.

Each operation refers to a "station". Each station represents a set of data stored in the computer memory, consisting of four arrays of data. Normally these arrays hold data representing daily mean discharges, stages, storage, and daily change in storage at each station, one value for each day of the period being simulated.

Initial values are input to some of the stations using computer input data. Other stations' values are filled in as necessary depending upon the function and configuration of the model. Each station has a unique identification number which is referenced in the model instructions whenever that data is to be used or modified by an operation. During the running of the program various individual operations comprising nodes of the model are called in sequence from an input list of model instructions, each telling the type of operation to be performed, the parameter values to be used, and the stations to be operated upon.

The main operating capabilities of the SIMPAK program are summarized below. More detailed descriptions and operating instructions for the program are provided in the SIMPAK User's Manual.

2.1.1 Data Input

There are several classes of data that are input to the program:

a) Model control data that define the stations for the model and specify the operations that are to be performed at each node. This data constitutes "the model". It is normally read from a computer disk file, but can also be input directly from cards or from a remote keyboard terminal.

   All operations are specified on a standard format, making the coding and punching of the operating instructions a relatively easy matter. All the parameters associated with that operation are contained in the single instruction.

b) Tables of relationships such as correlation curves, hydrologic relationships or other functions that are necessary in some operations. These are held on a separate data file, set up externally to the program, that is automatically searched for the required tables.

c) Hydrologic data such as records of discharges, elevations, etc. The program will read the required hydrologic data for the model from several different input sources such as card-image computer disk files, magnetic tape, and disk files holding unformatted data. On any of the data input units (i.e. cards, tape or disk) the data can be handled in any of three different data formats:

i) "W.S.C." format, card format 67-002 used by Water Survey of Canada on its computer data tapes;

ii) "SSARR" format, format used in the SSARR program for data input;

iii) "long records" format, made up of data records consisting of unformatted (i.e. machine code form) data.

Input instructions specify which sources are to be searched for the data. The program automatically searches all the data held in each of the specified sources to find the data required by the model. Data may be in any station order and unused data may be included in the data files. A flag on each data record tells whether the data is in English or metric units. Mixtures of English and metric data can be handled automatically in any job.

2.1.2 Data Output

SIMPAK outputs data in several forms. The most common is a listing of the discharges for each station, showing one month of mean daily discharges for eight stations on each page. Examples of such output are shown in Figure 2.8. If required, stages can also be printed alongside the corresponding discharges for each station, showing one month of mean daily discharges and stages for four stations on each page as illustrated in Figure 2.9. Note that only two stations were printed in Figure 2.9 to show the difference between observed stage and regulated stage for Sample River at Mouth.

The complete set of data for a station, i.e. discharge, elevation, storage, and change in storage, can be printed if specified by the input model instructions. This type of output is illustrated in Figure 2.10. The program will also output data to computer files in either the SSARR format or the long record format.

Two different types of plotting can be accomplished by the program. The most convenient type is the printer-plot, in which the printer output sheet is scaled and a hydrograph is "plotted" using printer symbols. This method provides a fast and inexpensive plot of any specified time-series data. Several stations can be plotted together to give a clear comparison of the data at those stations. An example of this type of plot is shown in Figure 2.11. The second type of plot, having the same features and format as the printer-plot, is the line-plot produced on a Calcomp or equivalent plotter.

All data output can be in either English or metric units, depending on the specifications in the model control instructions.

2.1.3 Model Time Control

The program works on a fixed time increment of one day, except in the SSARR reach routing operation in which calculations are automatically made for shorter time periods under certain conditions. All input and output flows are considered to be mean daily discharges. Values of elevation and storage are computed as the end of day values.

The time boundaries for any run are input in the model control instructions. This can be a number of years depending on the size of computer system used. All data is checked for the correct time period and only the data within that period is selected from the data files.

Any run of the program can be cycled to provide additional simulations for different time boundaries using the same input model. In such cases, the data applicable to the new cycle will be picked up automatically from the input data files.

2.1.4 Organization of the Program

Each set of data within the program is indexed according to a unique station number. All operations are then made by reference to these station numbers. Each operation is specified by an input operation card which tells the program what type of operation to carry out and specifies the stations and parameters to use. Each operation takes the data held in one or more stations, uses that data in carrying out the specified operation, and stores the computed values of the operation under another specified station number. In this way the operations specified in the model control list also specify the configuration of the river.

The four different types of data stored in the computer for each station are indexed as follows:

index 1 = discharges,
index 2 = elevations,
index 3 = storage,
index 4 = change in storage.

Thus, each station has an array for each of these four types of data. They are not necessarily all filled in with meaningful data, depending upon the operations that are carried out using that station.

There also may be tables associated with any station. If the operation being undertaken requires characteristic data or control data in addition to the parameters specified on the

control list, the program looks for a table having the station number as its identification.

2.1.5 Operations in SIMPAK

Each operation in a SIMPAK model is initiated by an entry in the model operation control list, a series of input data statements to the program. Each operation statement specifies what type of operation is to undertaken, what parameter values to use in the operation, and what stations and types of data are to be operated upon. In many operations only one of the four available types of data are used. In other operations, (for example, lake routing) all four types of data are used. The various operations in a model are linked together by specifying input stations and output stations for each operation, in such a way that the output from one operation becomes the input to another.

Examples of SIMPAK operations are:

a) ADD ... sums data from two or three stations;

b) LOOK ... computes discharge at a station from specified water surface elevations or vice-versa;

c) REACH ... routes flows through a river channel reach using the SSARR method of channel routing. This method is described in detail in Section 3.2.3. This is the routing operation used in the Yukon River model;

d) WAVE ... routes flows or reservoir holdouts to a downstream point using a polynomial method of routing (similar to a unit hydrograph). This method of routing is not used in the standard Yukon Basin model.

e) LAKE ... routes flows through a lake;

f) RESEV ... routes flows through a reservoir in a manner to fulfill reservoir operating criteria and rules.

These are the most common operations encountered in a daily routing model. There are about twenty-five such operations included in the SIMPAK program. In addition the program has a user-defined operation USER that allows SIMPAK users to program their desired operation to fit into the SIMPAK system.

2.2 Building a SIMPAK Model

2.2.1 The Conceptual Model

The foregoing discussion has briefly described the manner in which the SIMPAK program works. However, to make the program do some modelling, it is necessary to formulate a conceptual model of the river system and to calibrate that model so that it will produce results compatible with what would be observed on the river itself.

A sample conceptual model of a very simple system is shown in Figures 2.1 and 2.2. The conceptual model represents the river system by a series of interconnected nodes. Each node represents either a physical process at some area in the river or a logistics process required by the model, for example, reading data into computer memory or adding two stations' data, etc. The lines linking the nodes represent transfer of data in the model from one station to another. Solid lines represent a physical connection, i.e., flow from one station to another. Dashed or dotted lines represent functional relations such as estimating flows at one station based upon correlation with another station. Usually, each station in the model is represented by a node in the conceptual model.

Each station is given a unique number where the number may be arbitrary or may follow a logical key. In this example, the five digit numbers used follow the key that the first three digits represent a physical location along the river, the fourth digit represents the function of the node, and the last digit represents the source or type of data held by the station. This numbering code is described in detail in Table 2.1.

2.2.2 Model Control Data

Having derived the conceptual model, the user can prepare the model control data input. Note that several of the nodes may need to be calibrated to determine the correct parameters to use in the operation statements. Assuming that the parameters have already been determined, the model control data is coded according to the rules given in the SIMPAK User's Manual. For the sample model shown in Figures 2.1 and 2.2, the model control data is shown in Figure 2.3, and is described below.

The model control data is provided in 80-character long statements that may be provided to the computer either by computer cards or by sequential lines in a computer file. Although the instructions are referred to as "cards" in the descriptions below, they are usually prepared as lines in a file.

The first statement (or computer card image) is simply a title that will be printed on all pages of computer output. Following the title card are several cards that define each station used by the model. Each station card gives the station number, a code for the type of output listing for the station (1 means discharge output only), a code for timing of elevation data (usually this is blank or zero), and a station title.

Table 2.1: Station Number Coding System for the Yukon Basin Model

Each station in the model is specified by a station number made up of five or seven digits. These digits may be separated into three functional parts as shown below:

Auxiliary information used to distinguish stations holding special data or stations forming part of auxiliary models,
eg.
- "50" specifies routing stations within a "local flow" sub-model
- "90" specifies hydrometric data stations at which "filled in data" has been included.

Location number
- a unique number for each point on the river system (see maps).

Station function
- these two digits relate to the function of a station. They are described below:

(a) routing function digit;
- 0 input station (e.g. observed flows or pre-computed local flows).
- 1 project flows
- 2 "adjacent station" computation
- 4 reach routing computation
- 5 lake routing computation
- 6 reservoir routing computation
- 9 miscellaneous transfer point

(b) data function digit;
- 0 project outflows (only 10)
- 3 reservoir holdouts
- 4 lake levels
- 5 diversion flows
- 6 local inflows
- 7 net inflows
- 8 total inflows
- 9 recorded flows (09) or routing outflow points (e.g. 49 or 59)

Note that this system cannot be followed rigidly since many stations have more than one function.

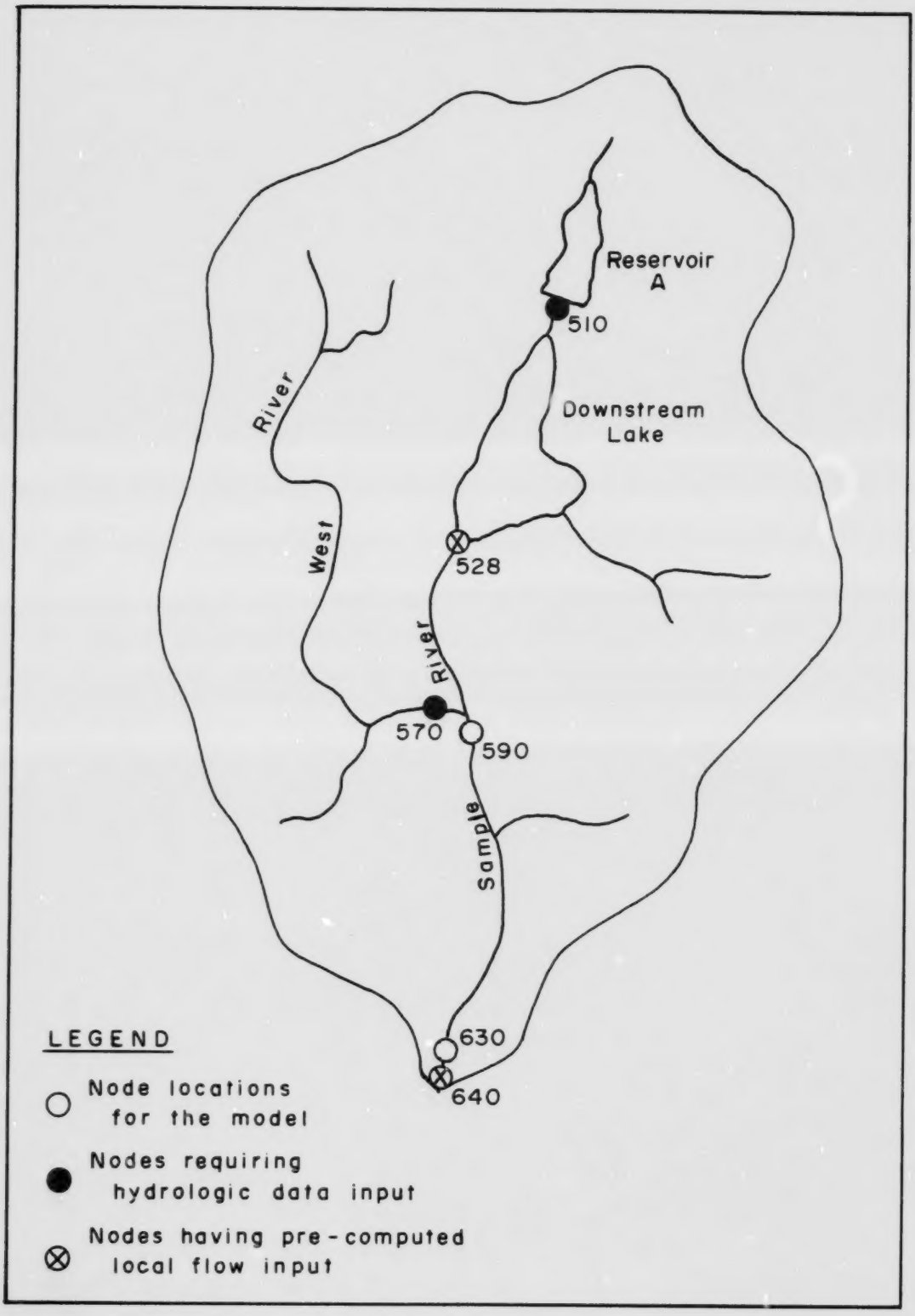


FIGURE 2.1: Map of Area to be Covered by Sample Model Showing Node Location

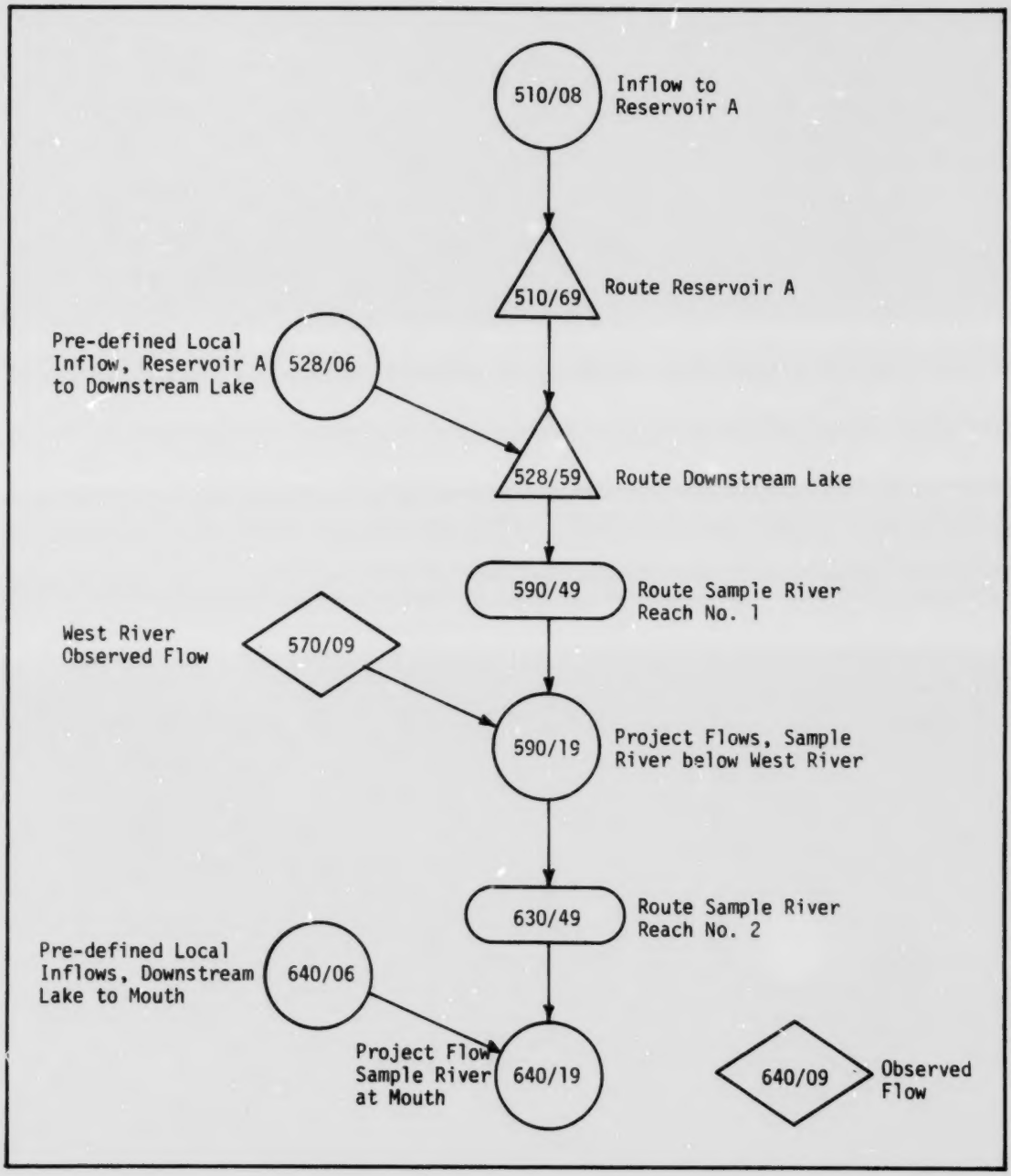


FIGURE 2.2: Schematic Flow Chart for Sample Model

```
DEMONSTRATION RUN, SHOWS SAMPLE ROUTING MODEL
        51008            1       INFLOW TO RESERVOIR A
        51069            9 1     RESERVOIR ROUTE, RESERVOIR A
        52806            1       PRE-DEFINED LOCAL INFLOW, RES A TO DWST LAKE
        52859            9 1     LAKE ROUTE, DOWNSTREAM LAKE
        59049            1       ROUTE SAMPLE RIVER, REACH NO. 1
        57009            1       WEST RIVER OBSERVED FLOW
        59019            1       PROJECT FLOWS, SAMPLE RIVER BELOW WEST RIVER
        63049            1       ROUTE SAMPLE RIVER, REACH NO. 2
        64006            1       PRE-DEFINED LOCAL INFLOW, DWST LAKE TO MOUTH
        64019           11       PROJECT FLOWS, SAMPLE RIVER AT MOUTH
        64009           11       OBSERVED FLOWS, SAMPLE RIVER AT MOUTH
$END
1  5 1980  31  7 1980      0    2    1    0    0    0    1    2    1
RESEV       51069       51008           -999999999 1 9 9  315770.
LAKE        52859       51069      52806                      56.63
REACH       59049       52859                          2        0.2       19.0
ADD         59019       59049      57009               1
REACH       63049       59019                          2        0.2       22.0
ADD         64019       63049      64006               1
LOOK        64019       64019                          2 1
LOOK        64009       64009                          2 1
PLOT                                                   2
          64019     1    C          0       5000
          64009     1    N          0       5000
$END
$END
```

FIGURE 2.3: SIMPAK Input Control Data

Following the station cards is an "END" card that signals the end of the station card list. This card is a "file end card" that must meet the specifications of the computer centre being used to run the program. It simply tells the computer system to stop reading input statements and to go back to the computer program for the next instruction.

Following the "END" card is the initialization card. This sets up the time constraints for the model and sets up many switches to determine how the program will operate in reading data, how it will operate in printing and filing output data, and how to interpret the operations cards. In this case the initialization card is interpreted as follows:

1,5,1980 ... the starting date

31,7,1980 ... the ending date

0 ... no WSC tape input

2 ... specifies two input files for hydrologic data (WSC format data on one file and SSARR format data on the other)

1 ... these are tables input

0 ... no "lead time" for WAVE routing (not applicable to this model)

0 ... a switch to call a specialized input routine (normally this is zero)

0 ... no long record files are required

1 ... will dump all output data upon an error termination

2 ... specifies a metric model (all parameters in the model control list are in metric units)

1 ... ignores the century specified on input SSARR data (i.e. dates are assumed twentieth century)

Next comes a series of operation cards. Each operation card specifies the station to be operated upon (i.e. where in the computer memory the results of the calculations will be stored) as well as the upstream stations that feed data to the operation. These cards also specify up to three integer

"variables" and three decimal "parameters" that may be used in the operations. Note that all operation cards follow a common format, although some (e.g., WAVE, MEAN and PLOT) require extra cards in a separate format.

Two of the operation cards in the sample model are described below. The first operation RESEV is described as follows:

RESEV signals the program that a reservoir routing operation is required.

51069 is the station to hold the data regarding the reservoir. The discharge, stage, storage, and change in storage will be computed for each day and will be held under this station number. The program will look under this station number for the reservoir control data.

51008 is the station holding the inflow to the reservoir. The day by day inflows will be found in the type 1 array (discharges) for this station.

1 tells the program that the reservoir control data are discharges. They will be found in the type 1 array for station 51069. Note that these controlling discharges are read into the computer from the hydrologic input data.

9 the switch to suppress elevation bounds is turned on (i.e. elevation bounds will be neglected).

9 the switch to suppress discharge constraints is turned on (i.e. the specified minimum discharge as

well as a maximum discharge capacity will be neglected).

256,000 is the starting value of storage for the reservoirs (in units of 1000 cubic metres)

Note that since this is a metric model (specified in the initialization card) all parameter values are in metric units.

The fourth operation ADD is described as follows:

ADD signals the program that an ADD operation is required.

59019 is the station to hold the results of the ADD operation.

59049 is the station that holds one set of data to be added.

57009 is a station that holds a second set of data to be added

1 tells the program that type 1 data (discharges) are to be used at all stations specified.

The above two operations are described only as samples to provide an appreciation of how a model works. Different operations have different parameters in the operation cards. Also there are default values for many of the parameters that will automatically apply if no others are specified. The detailed instructions for all of these characteristics of all operations are given in the SIMPAK User's Manual.

Following the operation cards is another file "END" card. The whole model can be recycled for another time period by a "CYCLE" card for each additional period. If no further cycles are required, another file "END" card is included to signal the end of the model run.

2.2.3 Additional Input Data

As well as the model control data, described above, the model requires various other types of input data. For the sample model, tables data are required as well as two sets of hydrologic data. The various sources of data allowed by the program are described in the SIMPAK User's Manual. In this sample, the initialization card specifies that data will be expected from three different sources; tables (expected by the program on computer logical unit 8), SSARR format hydrologic data (unit 16) and WSC format hydrologic data (unit 1). In addition, a cross-reference file of station numbers to relate the model station numbers to the WSC station numbers is expected on logical unit 14 (note that this is required whenever WSC formatted data is read from disk files). The model control data, described above, is expected on logical unit 5. All this data must be provided to the correct computer logical unit prior to the run of the SIMPAK program. This is easily and conveniently done using computer files. Each set of data is read into a file. Then the run control statement (dependent upon the computer centre being used) must equate the name of each file with the relevant logical unit. By this method, large data files held on computer disk files may be accessed by many different runs of the program and it is not necessary to read in the data each time.

As well as the input units, several additional files are needed by the SIMPAK program to function properly. These also must be set up externally to the program and must be defined in the run

instructions. This is easily done by anyone with a working knowledge of the computer centre being utilized. These additional files are noted in the SIMPAK User's Manual. One "scratch file" is always required on unit 4. Also, a printer output file on unit 6 is required (on most systems this automatically prints on the printer if not specifically defined). Additional output files are required for specialized operations such as CALP (line plotting), MEAN (outputs monthly mean and total discharges), FILE and WLNR (two operations for filing station data). All these output files can be either stored on computer disk files for future use, or printed directly on the printer, depending on how the output units are specified on the run instruction.

The input files needed for the sample model are shown in Figures 2.3 to 2.7. Figure 2.3 is the model control data that has already been described. Figure 2.4 is the tables data. Figures 2.5 and 2.6 are hydrologic input data, and Figure 2.7 is the cross-reference file.

The tables file must contain a table for every station at which elevations or storage values are to be computed. Thus, for the sample model there are tables for stations 51069 (for RESEV), and 52859 (for LAKE). The tables are set up in a standard format:

Columns
- 2-10 ..... station number
- 11-15 ..... units specification (0 or blank specifies English units)
- 16-20 ..... card sequence number
- 21-30 ..... elevation
- 31-40 ..... storage
- 41-50 ..... discharge
- 51-60 ..... time of storage (can be used in operation REACH).

52859	2	1	1.28	4407.	0.	0.
52859	2	2	1.31	4512	18.	0.
52859	2	3	1.34	4617.	20.	0.
52859	2	4	1.37	4722.	22.	0.
52859	2	5	1.43	4931.	28.	0.
52859	2	6	1.46	5036.	32.	0.
52859	2	7	1.52	5246.	43.	0.
52859	2	8	1.58	5456.	56.	0.
52859	2	9	1.62	5561.	63.	0.
52859	2	10	1.68	5770.	79.	0.
52859	2	11	1.86	6301.	147.	0.
52859	2	12	1.98	6803.	204.	0.
52859	2	13	2.13	7344.	289.	0.
52859	2	14	2.38	8183.	447.	0.
52859	2	15	2.53	8708.	560.	0.
52859	2	16	2.77	9547.	753.	0.
52859	2	17	2.90	9967.	855.	0.
52859	2	18	3.05	10492.	990.	0.
52859	2	19	3.20	11019.	1130.	0.
52859	2	20	3.35	12075.	1430.	0.
52859	2	21	3.66	13133.	1740.	0.
52859	2	22	3.96	13133.	2070.	0.
52859	2	23	4.57	16328.	2776.	0.
52859	2	24	6.10	21693.	4760.	0.
51069	2	1	481.58	7.	0.	0.
51069	2	2	512.06	20600.	0.	0.
51069	2	3	524.26	53000.	0.	0.
51069	2	4	542.54	154000.	0.	0.
51069	2	5	560.83	316000.	923.	0.
51069	2	6	568.45	405000.	991.	0.
51069	2	7	574.55	471000.	1019.	0.
51069	2	8	580.64	544000.	1048.	0.
51069	2	9	586.74	625000.	1048.	0.
51069	2	10	598.93	791000.	1104.	0.
51069	2	11	601.68	835000.	1104.	0.
51069	2	12	602.28	842000.	1161.	0.
51069	2	13	603.50	857000.	1416.	0.
51069	2	14	605.03	883000.	1926.	0.
51069	2	15	608.08	933000.	3285	0.
51069	2	16	611.12	982000.	5012.	0.
51069	2	17	670.56	2097000.	26900.	0.
51069	2	18	700.00	3000000.	40000.	
64019	2	1	1.0		0.	
64019	2	2	2.0		500.	
64019	2	3	3.0		1500.	
64019	2	4	4.0		3000.	
64019	2	5	5.0		6000.	
64009	2	1	1.0		0.	
64009	2	2	2.0		500.	
64009	2	3	3.0		1500.	
64009	2	4	4.0		3000.	
64009	2	5	5.0		6000.	

FIGURE 2.4: Table Data for Sample Model

9D19	64006	12	1	5801	235	241	245	249	258	268	281	292
9D19	64006	12	9	5801	306	317	334	348	362	396	430	464
9D19	64006	12	17	5801	493	521	549	572	597	634	685	731
9D19	64006712		25	5801	767	790	804	844	895	926	985	
9D19	64006	12	1	6801	1048	1107	1141	1178	1201	1223	1246	1274
9D19	64006	12	9	6801	1300	1342	1385	1464	1478	1478	1461	1455
9D19	64006	12	17	6801	1447	1441	1433	1413	1393	1373	1348	1331
9D19	640066	12	25	6801	1317	1308	1300	1286	1277	1263		
9D19	64006	12	1	7801	1254	1223	1212	1201	1178	1155	1136	1121
9D19	64006	12	9	7801	1107	1090	1053	1053	1070	1076	1090	1093
9D19	64006	12	17	7801	1085	1068	1048	1025	1017	898	974	954
9D19	640067	12	25	7801	920	915	878	864	844	813	787	
9D19	52806	12	1	5801	29	45	54	58	61	69	62	64
9D19	52806	12	9	5801	72	96	118	159	212	241	249	237
9D19	52806	12	17	5801	224	213	199	207	284	347	336	169
9D19	528067	12	25	5801	174	222	327	341	459	593	665	
9D19	52806	12	1	6801	633	509	412	397	394	423	469	548
9D19	52806	12	9	6801	602	692	760	705	474	361	352	408
9D19	52806	12	17	6801	445	386	330	348	391	336	306	327
9D19	528066	12	25	6801	364	384	329	403	587	527		
9D19	52806	12	1	7801	372	280	241	240	258	277	298	388
9D19	52806	12	9	7801	392	316	235	306	401	418	349	292
9D19	52806	12	17	7801	270	243	223	181	167	173	164	174
9D19	528067	12	25	7801	169	158	145	133	128	123	116	
9D19	51069	12	1	5801	42	66	79	86	89	98	88	90
9D19	51069	12	9	5801	107	143	179	235	315	356	359	332
9D19	51069	12	17	5801	309	290	280	299	426	525	485	281
9D19	510697	12	25	5801	0	0	0	0	0	0	0	
9D19	51069	12	1	6801	0	0	0	0	0	0	0	0
9D19	51069	12	9	6801	0	0	0	0	0	0	0	0
9D19	51069	12	17	6801	0	0	0	0	0	0	0	0
9D19	510696	12	25	6801	0	0	0	0	0	0		
9D19	51069	12	1	7801	500	381	346	358	395	429	463	595
9D19	51069	12	9	7801	577	450	337	429	577	601	499	424
9D19	51069	12	17	7801	410	374	342	288	276	284	303	311
9D19	510697	12	25	7801	294	268	249	232	228	214	204	
9D19	51008	12	1	5801	42	66	79	86	89	98	88	90
9D19	51008	12	9	5801	107	143	179	235	315	356	359	332
9D19	51008	12	17	5801	309	290	280	299	426	525	485	281
9D19	510087	12	25	5801	267	316	438	488	662	844	942	
9D19	51008	12	1	6801	876	685	557	538	547	606	661	776
9D19	51008	12	9	6801	862	996	1106	1029	668	499	495	603
9D19	51008	12	17	6801	655	542	464	503	573	483	440	470
9D19	510086	12	25	6801	529	554	473	592	842	723		
9D19	51008	12	1	7801	500	381	346	358	395	429	463	595
9D19	51008	12	9	7801	577	450	337	429	577	601	499	424
9D19	51008	12	17	7801	410	374	342	288	276	284	303	311
9D19	510087	12	25	7801	294	268	249	232	228	214	204	

FIGURE 2.5: SSARR Format Hydrologic Data for Sample Model

```
Q08XYO24980 51  132  145  165  187  205  221  229  235  248  289   31
Q08XYO24980 52  337  402  493  595  677  711  745  736  714  719
Q08XYO24980 53  810  980 1100 1040  934  872  886  936 1100 1270 1410
Q08XYO24980 61 1480 1470 1380 1240 1170 1160 1190 1260 1340 1440   30
Q08XYO24980 62 1540 1600 1560 1420 1190 1090 1120 1120 1030  966
Q08XYO24980 63  974  950  906  892  926  974  932  936 1030 1050
Q08XYO24980 71 1000  860  770  711  705  719  736  779  835  807   31
Q08XYO24980 72  708  690  804  886  864  782  725  680  646  592
Q08XYO24980 73  552  532  524  521  515  496  473  447  433  425  402
Q08XZ001980 51  382  433  490  547  592  631  663  680  705  765   31
Q08XZ001980 52  875 1020 1210 1460 1650 1750 1790 1790 1780 1780
Q08XZ001980 53 1930 2260 2560 2500 2260 2160 2270 2500 2830 3310 3790
Q08XZ001980 61 4050 3990 3710 3460 3340 3370 3480 3680 3960 4280   30
Q08XZ001980 62 4616 4840 4560 4080 3620 3480 3570 3570 3400 3230
Q08XZ001980 63 3256 3230 3090 3000 3060 3140 3140 3110 3370 3600
Q08XZ001980 71 3426 3000 2690 2540 2500 2530 2580 2700 2870 2810   31
Q08XZ001980 72 2540 2410 2600 2860 2920 2740 2560 2430 2320 2190
Q08XZ001980 73 2070 1890 1960 1950 1910 1880 1790 1720 1650 1590 1540
```

FIGURE 2.6: WSC Format Hydrologic Data for Sample River

```
08XYO24     57009
08XZ001     64009
```

FIGURE 2.7: WSC Data Cross-Reference File for Sample Model

In some models there are also "backwater tables" having a different format. These are described in the SIMPAK User's Manual.

The hydrologic input data includes all input hydrometric data as well as control data (levels or controlled discharges) for reservoirs. This data may be input through any of several different source files; WSC card images from files or a card reader, SSARR format files or cards, or "long record" (machine code) files. In this sample two of these are used; SSARR format files and WSC card image files.

The data in the SSARR data files can be understood by the following description of the fourth line in the file shown in Figure 2.5:

```
      9D ..... code to identify the format and units
               (i.e., metric units and SSARR format)
      19 ..... century number (not normally used)
   64006 ..... station number
       7 ..... specifies the number of data values on the
               card (defaults to 8)
      12 ..... hour for data (not used by SIMPAK)
25, 5, 80 ..... date of first value on the card
       1 ..... code for the type of data (1 specifies dis-
               charge, 2 elevation, 3 storage and 4 change
               in storage).
```

These are followed by up to eight values, one for each day starting with the date specified on the card.

Likewise, the data in the WSC data files can be understood by the following description of the first line in the file shown in Figure 2.6:

```
      Q ..... a code for the type and units of data (1
              specifies discharge in cubic metres per
              second)
 8XY024 ..... the WSC station number (a hypothetical
              station)
    980 ..... the year 1980
      5 ..... the month of the year
      1 ..... indicates this is the first of three cards
              for the month.
```

This is followed by eleven data values per card. The first ten are used for hydrometric data. The eleventh on the 1st card

each month holds the number of days in the month. The eleventh on the third card is data for the 31st day if necessary.

Whenever WSC data is used, a cross-reference file must be provided to link the model station numbers with the WSC station numbers. This file contains the WSC number and the corresponding model station number of each station required from the WSC data. A sample is shown in Figure 2.7.

Note that all these hydrologic data files and tables files may contain many stations that are not required by the model. The computer program searches these files to find the data required by the model.

All the specified files are accessed by the SIMPAK program and data for all stations listed in the "stations cards" are automatically read by the program if they occur in the files. Then the instructions provided by the model control data are followed so as to operate the model.

2.2.4 Output Data

The results of the simulation are output either to computer files, printers or plotters as specified by the model control data. Output for the sample model is shown in Figures 2.8, 2.9 and 2.10. Figure 2.8 is the first type of the short-form printed output that lists only the discharge at specified stations. Figure 2.9 is the second type of the short-form printed output that lists both the stage and discharge at specified stations. Figure 2.10 is detailed output that lists all four data types for a station. Figure 2.11 is a printer plot showing hydrographs.

DEMONSTRATION RUN. SHOWS SAMPLE ROUTING MODEL

OUTFLOW (CMS)

51008	INFLOW TO RESERVOIR A
52806	PRE-DEFINED LOCAL INFLOW, RES A TO DWST LAKE
59049	ROUTE SAMPLE RIVER, REACH NO 1
57009	WEST RIVER OBSERVED FLOW
59019	PROJECT FLOWS, SAMPLE RIVER BELOW WEST RIVER
63049	ROUTE SAMPLE RIVER, REACH NO 2
64006	PRE-DEFINED LOCAL INFLOW, DWST LAKE TO MOUTH

DATE	STATION 51008	STATION 52806	STATION 59049	STATION 57009	STATION 59019	STATION 63049	STATION 64006	STATION
1 JUNE 1980	876.00	633.00	648.10	1480.00	2128.10	2091.44	1048.00	
2 JUNE 1980	685.00	509.00	568.52	1470.00	2038.52	2073.63	1107.00	
3 JUNE 1980	557.00	412.00	461.07	1380.00	1841.07	1919.43	1141.00	
4 JUNE 1980	538.00	397.00	405.91	1240.00	1645.91	1724.95	1178.00	
5 JUNE 1980	547.00	391.00	395.76	1170.00	1565.76	1599.39	1201.00	
6 JUNE 1980	606.00	423.00	407.95	1160.00	1567.95	1567.42	1223.00	
7 JUNE 1980	661.00	469.00	444.66	1190.00	1634.66	1606.89	1246.00	
8 JUNE 1980	776.00	548.00	507.36	1260.00	1767.36	1712.12	1274.00	
9 JUNE 1980	862.00	602.00	574.46	1340.00	1914.16	1853.77	1300.00	
10 JUNE 1980	996.00	692.00	647.69	1440.00	2087.69	2017.36	1342.00	
11 JUNE 1980	1106.00	760.00	727.28	1540.00	2267.28	2195.53	1385.00	
12 JUNE 1980	1029.00	705.00	730.45	1600.00	2330.45	2305.36	1464.00	
13 JUNE 1980	668.00	474.00	583.99	1560.00	2143.99	2216.12	1478.00	
14 JUNE 1980	499.00	361.00	418.11	1420.00	1838.11	1958.17	1478.00	
15 JUNE 1980	495.00	352.00	358.24	1190.00	1548.24	1665.33	1461.00	
16 JUNE 1980	603.00	408.00	378.70	1090.00	1468.70	1502.79	1455.00	
17 JUNE 1980	655.00	445.00	424.46	1120.00	1544.46	1513.09	1447.00	
18 JUNE 1980	542.00	386.00	415.92	1120.00	1535.92	1539.10	1441.00	
19 JUNE 1980	464.00	330.00	360.09	1030.00	1390.09	1451.01	1433.00	
20 JUNE 1980	503.00	348.00	339.52	966.00	1305.52	1342.09	1413.00	
21 JUNE 1980	573.00	391.00	367.58	974.00	1341.58	1326.69	1393.00	
22 JUNE 1980	483.00	336.00	364.26	950.00	1314.26	1325.73	1373.00	
23 JUNE 1980	440.00	306.00	323.04	906.00	1229.04	1265.76	1348.00	
24 JUNE 1980	470.00	327.00	315.10	892.00	1207.10	1217.20	1331.00	
25 JUNE 1980	529.00	364.00	343.40	926.00	1269.40	1242.46	1317.00	
26 JUNE 1980	554.00	384.00	372.55	974.00	1346.55	1312.68	1308.00	
27 JUNE 1980	473.00	329.00	357.65	932.00	1289.65	1313.53	1300.00	
28 JUNE 1980	592.00	403.00	364.97	936.00	1300.97	1296.49	1286.00	
29 JUNE 1980	842.00	587.00	489.32	1030.00	1519.32	1425.31	1277.00	
30 JUNE 1980	723.00	527.00	555.18	1050.00	1605.18	1567.69	1263.00	
MEAN	641.90	453.40	455.04	1177.87	1632.91	1638.28	1323.70	
MIN	440.00	306.00	315.10	892.00	1207.10	1217.20	1048.00	
MAX	1106.00	760.00	730.45	1600.00	2330.45	2305.36	1478.00	

FIGURE 2.8: SIMPAK Output — First Type of Short Form

DEMONSTRATION RUN. SHOWS SAMPLE ROUTING MODEL

64019 PROJECT FLOWS. SAMPLE RIVER AT MOUTH
64009 OBSERVED FLOWS. SAMPLE RIVER AT MOUTH

DATE	*** STATION *** 64019		*** STATION *** 64009		*** STATION ***	*** STATION ***
	OUTFLOW (CMS)	ELEVATION (METERS)	OUTFLOW (CMS)	ELEVATION (METERS)		
1 JUNE 1980	3139.44	4.05	4050.00	4.35		
2 JUNE 1980	3180.63	4.06	3990.00	4.33		
3 JUNE 1980	3060.43	4.02	3710.00	4.24		
4 JUNE 1980	2902.95	3.94	3460.00	4.15		
5 JUNE 1980	2800.39	3.87	3340.00	4.11		
6 JUNE 1980	2790.41	3.86	3370.00	4.12		
7 JUNE 1980	2852.89	3.90	3480.00	4.16		
8 JUNE 1980	2986.12	3.99	3680.00	4.23		
9 JUNE 1980	3153.77	4.05	3960.00	4.32		
10 JUNE 1980	3359.36	4.12	4280.00	4.43		
11 JUNE 1980	3580.53	4.19	4616.00	4.54		
12 JUNE 1980	3769.36	4.26	4840.00	4.61		
13 JUNE 1980	3694.12	4.23	4560.00	4.52		
14 JUNE 1980	3436.17	4.15	4080.00	4.36		
15 JUNE 1980	3126.33	4.04	3620.00	4.21		
16 JUNE 1980	2957.79	3.97	3480.00	4.16		
17 JUNE 1980	2960.09	3.97	3570.00	4.19		
18 JUNE 1980	2980.10	3.99	3570.00	4.19		
19 JUNE 1980	2884.01	3.92	3400.00	4.13		
20 JUNE 1980	2755.09	3.84	3230.00	4.08		
21 JUNE 1980	2719.69	3.81	3256.00	4.09		
22 JUNE 1980	2698.73	3.80	3230.00	4.08		
23 JUNE 1980	2613.76	3.74	3090.00	4.03		
24 JUNE 1980	2548.20	3.70	3000.00	4.00		
25 JUNE 1980	2559.45	3.71	3060.00	4.02		
26 JUNE 1980	2620.68	3.75	3140.00	4.05		
27 JUNE 1980	2613.53	3.74	3140.00	4.05		
28 JUNE 1980	2582.49	3.72	3110.00	4.04		
29 JUNE 1980	2702.30	3.80	3370.00	4.12		
30 JUNE 1980	2830.69	3.89	3600.00	4.20		
MEAN	2961.98	3.94	3609.40	4.20		
MIN.	2548.20	3.70	3000.00	4.00		
MAX.	3769.36	4.26	4840.00	4.61		

FIGURE 2.9: SIMPAK Output — Second Type of Short Form

DEMONSTRATION RUN, SHOWS SAMPLE ROUTING MODEL

STATION 52859

LAKE ROUTE, DOWNSTREAM LAKE

DATE	OUTPUT (CMS)	ELEVATION (METER)	STORAGE (KCM)	DELTA STORAGE (CMS DAYS)
1 JUNE 1980	640.07	2.54	8751.	-7.07
2 JUNE 1980	514.88	2.40	8243.	-5.88
3 JUNE 1980	417.16	2.27	7797.	-5.16
4 JUNE 1980	394.53	2.33	8011.	2.47
5 JUNE 1980	396.26	2.27	7816.	-2.26
6 JUNE 1980	418.14	2.40	8236.	4.86
7 JUNE 1980	467.97	2.42	8325.	1.03
8 JUNE 1980	541.30	2.59	8904.	6.70
9 JUNE 1980	602.28	2.58	8880.	-0.28
10 JUNE 1980	683.58	2.79	9607.	8.42
11 JUNE 1980	760.67	2.77	9550.	-0.67
12 JUNE 1980	709.45	2.66	9165.	-4.45
13 JUNE 1980	493.11	2.18	7514.	-19.11
14 JUNE 1980	356.62	2.29	7892.	4.38
15 JUNE 1980	356.40	2.18	7512.	-4.40
16 JUNE 1980	398.63	2.42	8321.	9.37
17 JUNE 1980	448.27	2.34	8039.	-3.27
18 JUNE 1980	389.70	2.24	7719.	-3.70
19 JUNE 1980	333.24	2.16	7439.	-3.24
20 JUNE 1980	343.50	2.27	7828.	4.50
21 JUNE 1980	389.81	2.30	7931.	1.19
22 JUNE 1980	342.98	2.13	7328.	-6.98
23 JUNE 1980	303.83	2.18	7515.	2.17
24 JUNE 1980	326.37	2.20	7570.	0.63
25 JUNE 1980	360.44	2.29	7877.	3.56
26 JUNE 1980	384.59	2.27	7826.	-0.59
27 JUNE 1980	334.56	2.13	7346.	-5.56
28 JUNE 1980	390.87	2.44	8394.	12.13
29 JUNE 1980	578.14	2.66	9160.	8.86
30 JUNE 1980	540.18	2.33	8021.	-13.18
MEAN	453.92	2.37	8151.	-0.52
MIN.	303.83	2.13	7328.	-19.11
MAX.	760.67	2.79	9607.	12.13

FIGURE 2.10: SIMPAK Output — Detailed Printout

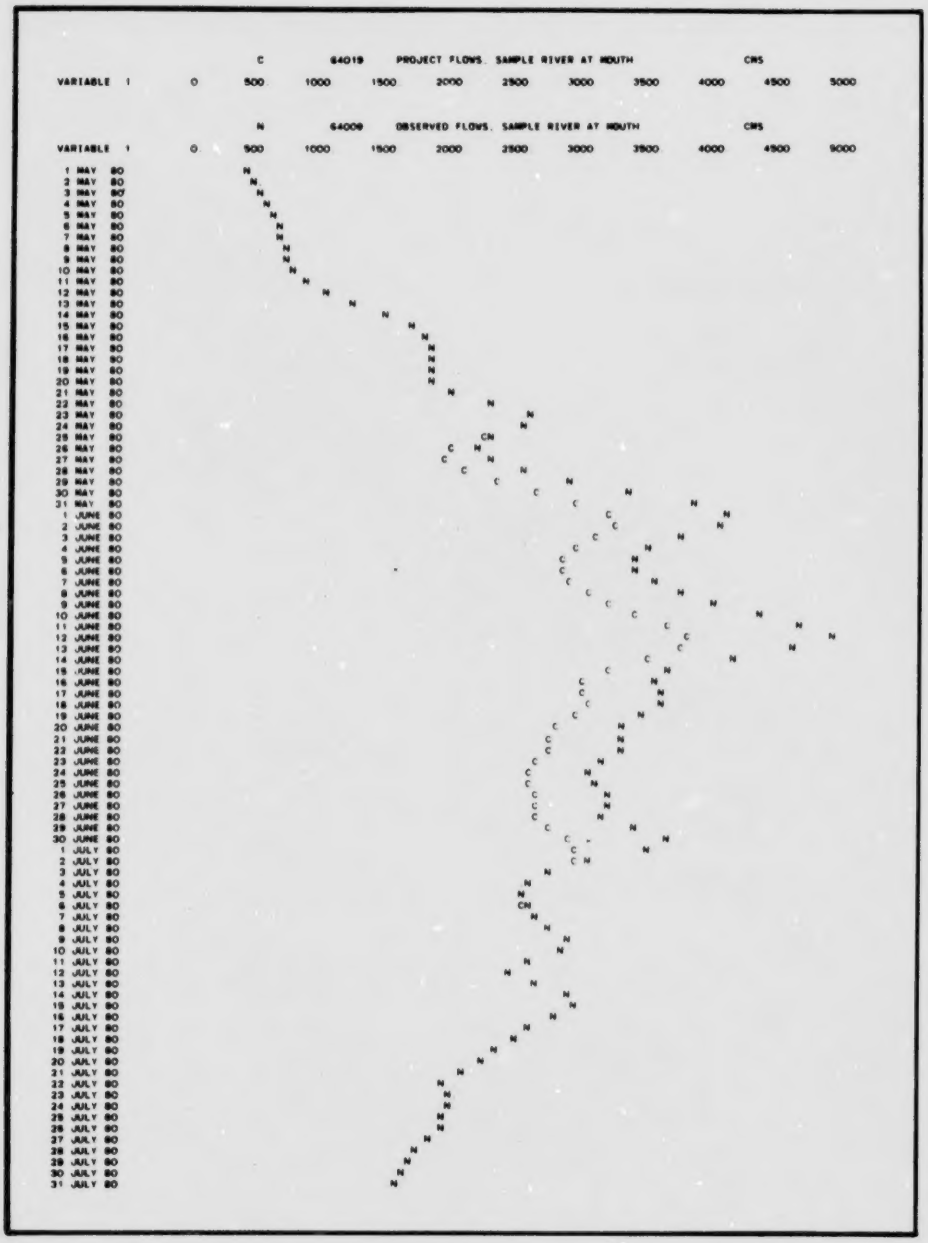


FIGURE 2.11: SIMPAK Printer Plot Output

CHAPTER 3
MODELLING WITH SIMPAK

This chapter describes various ways of using a daily routing model to simulate typical hydrologic conditions encountered in river routing problems. It shows the way in which the river can be simulated by a number of model "nodes" in a given configuration and describes how the operations at the nodes are calibrated to fit the conditions observed on the river. The chapter also outlines the ways in which a model may be modified to add additional tributaries or to insert a project into the model.

3.1 Sample River Configuration

In Section 2.2 a sample model was discussed. A map of a basin was shown and the way the river system could be conceptualized and coded as model control data for SIMPAK was illustrated. That sample showed only a few of the many situations encountered in river routing models. Several additional river configurations for sample problems in river routing and natural flow computations are given in the following pages. Each configuration displays the physical river pattern, the flow chart of the conceptual model and the list of operation cards (shows only the first five fields) needed for the model control data. A brief explanation is provided in each case. The symbols used in the flow charts to represent the features of the model are defined in Figure 3.1.

3.1.1 Channel Routing

In the example of Figure 3.2 streamflow is routed from Station A (1000) to Station B (2000) using a REAC operation. (Note REAC and REACH are the same operation). The routing operation is assigned a model number of 1500. Note that Station 2000 is not really needed in this model as all the required information is at Station 1500.

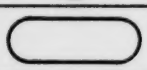
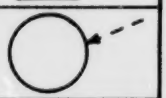
PHYSICAL FEATURES	CONFIGURATION SYMBOL
1. Gauging Station (either recorded or computed values)	
2. River confluence or summation point	
3. River Routing Reach	
4. Reservoir or Lake	
5. Flow Represented as a Function of another Station or Stations	

FIGURE 3.1: Drainage Basin Physical Features as Represented in Flow Chart

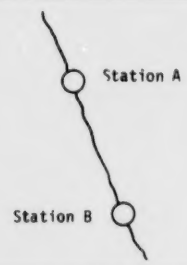
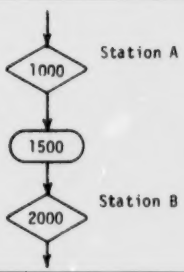
PICTORAL	FLOW CHART	OPERATION CARD SEQUENCE
		REAC 1500 1000 TRSF 2000 1500

FIGURE 3.2: Example of Channel Routing

3.1.2 Ungauged Local Inflow Estimated, Forecasting Models

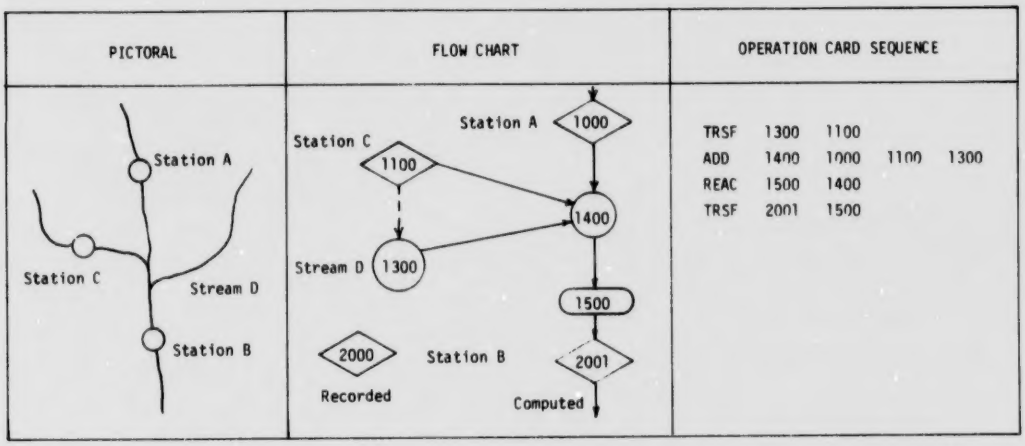


FIGURE 3.3: Example of Local Inflows (Forecasting Models)

In Figure 3.3 flow between Station A (1000) and Station B (2000) is supplemented by two streams. One stream is gauged by Station C (1100), and one is an ungauged Stream D (1300). The flow of Stream D is determined by a functional relationship (usually percentage of areas) from Station C. The flow is then routed downstream, using a REAC operation for Station 1500, to Station B (2001). Note that Station 2001 is not really needed as all the required information is at Station 1500 and that the recorded value for Station B (2000) is needed only for comparison.

This is the method employed by a forecasting model where local ungauged inflows must be estimated. In a project model, ungauged inflows can be computed as in the next example.

3.1.3 Ungauged Local Inflow Computed, Project Models

This situation is similar to the previous example, except the model is being prepared as a project model. Here the observed

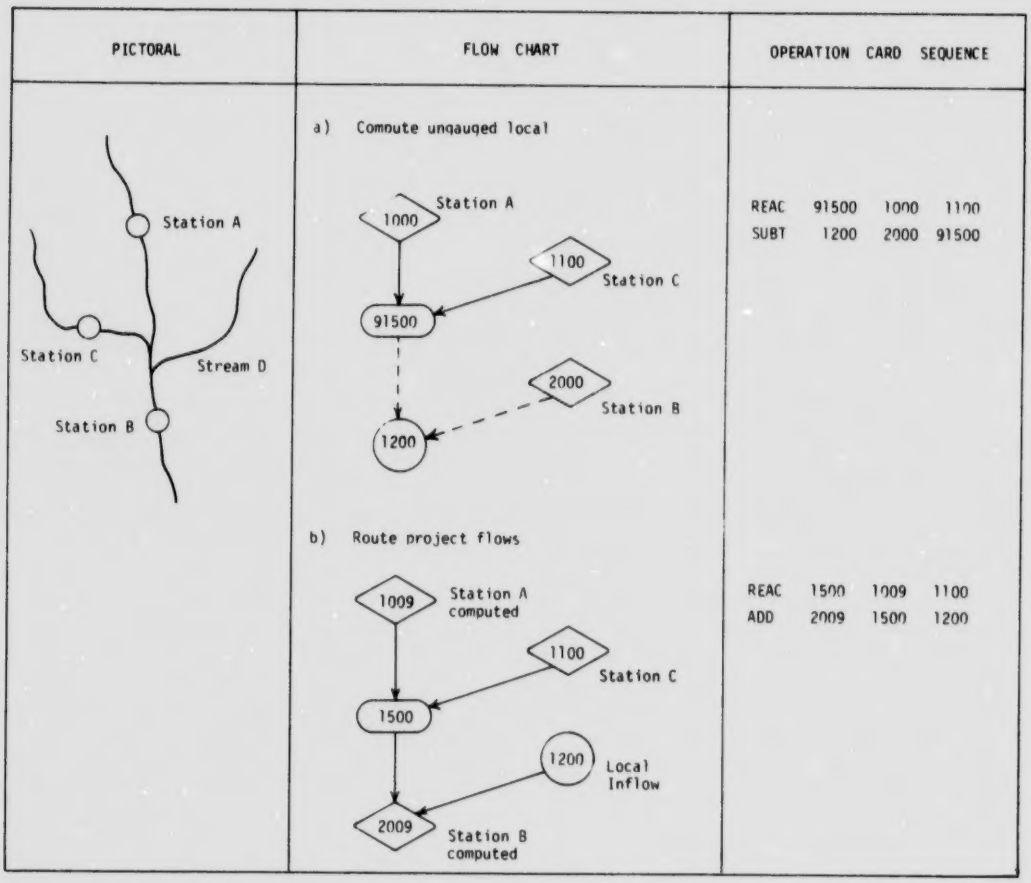


FIGURE 3.4: Example of Local Inflows (Project Models)

flows at gauge points along the river will always be known when running the model and the ungauged local flows can be computed from them.

In Figure 3.4 (a) the recorded streamflow data (1000 and 1100) is routed down to Station B. The routed flows are then subtracted from the gauged flows at B (2000) to produce the computed local inflow (1200). These computed local inflows are normally pre-computed in a separate model for later use in a regulated flow model.

The equivalent portion of the project model is shown in Figure 3.4 (b). Here the gauged flow (1000) is replaced by a simulated regulated flow (1009) being either the output of a reservoir being studied or the routed result of an upstream project. This is routed through the reach and then the pre-computed local flow is added to give regulated flows (2009) eqivalent to the gauged flows. Here the computed local inflow may be thought of as an adjustment to the model to add the observed local inflows and to make it compatible with recorded flows. In this way the regulated flows and the recorded flows are directly comparable having no error introduced by estimating local inflows.

This is the normal method of handling ungauged local flows in the Yukon Basin Model.

3.1.4 Lake and Reservoir Routing

Lakes without a backwater effect on their outflow are treated as shown in Figure 3.5. Flow enters from Station A (1000) and is routed through Lake C (1200). Tables data are used for the relationship of elevation, outflow and lake capacity for Lake C. The lake outflow is computed each day as a function of the lake's inflow and storage. The outflow can then be REACH

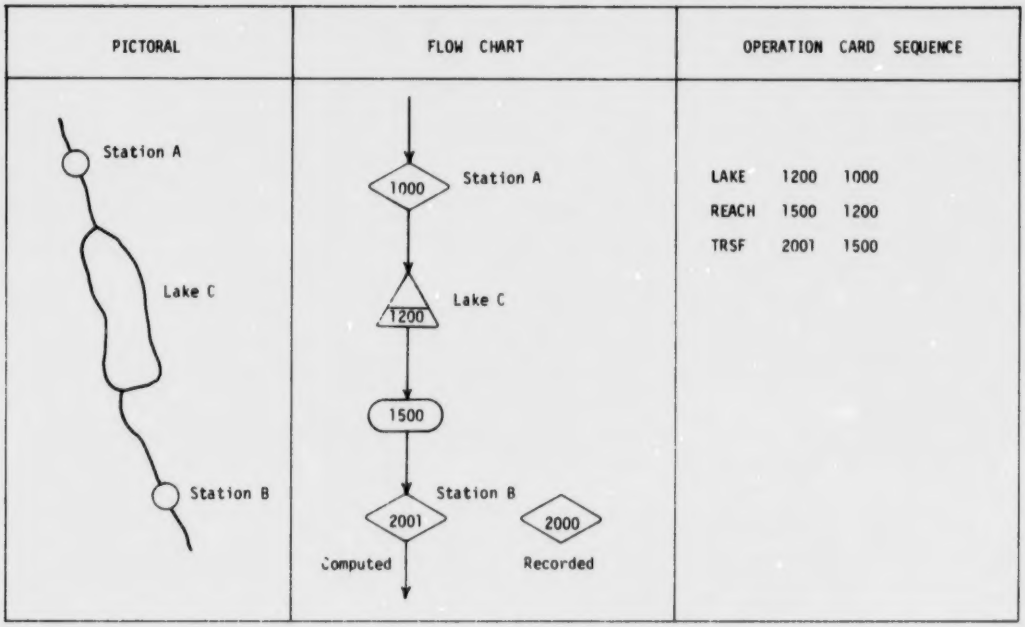


FIGURE 3.5: Example of Lake Routing

routed (1500) downstream to Station B (2001) if necessary. Point 2000 is the recorded values for Station B, used for comparison only.

Lakes with a backwater effect at their outlet require a more complex treatment. The Yukon Basin Model at present does not include any such backwater lakes although it is suggested that future work should attempt to separate Tagish and Bennett Lakes from Marsh Lake in a backwater relationship. The methods for handling backwater lakes are described in the SIMPAK User's Manual.

The model configuration for reservoir routing (operation RESEV) is identical to that for a lake routing. Reservoir routing is similar to lake routing except that the reservoir outflows are not computed in the same manner as a lake but are specified to the program as discharges, reservoir elevations, or storage contents.

3.2 Calibrating the Yukon Basin Model

Several of the nodes in the Yukon Basin model had to be calibrated, or in other words parameter values for the SIMPAK operations had to be determined so as to match the characteristics of the river system. This section describes the methods used in calibrating the model.

3.2.1 Lake Routing (Operation LAKE)

A lake routing operation defines the lake characteristics by a table of elevation versus lake discharge and elevation versus lake storage. These two relationships must be determined for the lake. The storage relationship can usually be determined to sufficient accuracy from available contour maps. The discharge relationship, however, normally requires discharge measurements to be taken either at the lake outlet or somewhere nearby downstream.

If no records of lake storage are available the relationship may be determined by trial and error solution for discharge. In this case the storage/elevation and discharge/elevation relationships are adjusted from one trial to another until a best-fit of the discharge information is reached.

If there are no records of any kind, the relationships may be formulated from hydraulic computations using the cross-section of the lake outlet and the slope of the river, etc.

The lake routing computations follow the "Pulse Method". This is described in most hydrologic text-books.

3.2.2 Reservoir Routing (Operation RESEV)

As in a lake, a reservoir must have a stage versus storage relationship. This is normally available from the reservoir

design criteria or the reservoir operating studies. If not, it can be easily computed from topographic maps. The outlet capacity (i.e. maximum discharge versus stage) may be used in the operation or may be neglected if the flow constraint override switch is turned on. The maximum discharge capacity is the total of all outlet works' capacities with all gates wide open.

The reservoir routing computations simply balance all reservoir data (stage, storage, and discharge) to suit the specified control data. If the control data exceeds the maximum discharge capacity, the discharge will be recomputed as if the reservoir were a lake.

3.2.3 SSARR Reach Routing (Operation REACH or REAC)

This operation is the most difficult to calibrate and to explain. The operation is described in detail in following sections.

3.2.3.1 Basic Channel Storage Equation

Figure 3.6 pictures schematically a section of river channel during a period of rising discharge. For this reach, the following basic water balance equation can be written:

Volume entering at A - Volume leaving at B = Change in channel storage

This equation can be expressed using the average discharge at the upstream and downstream ends of the reach; the discharge at A is the inflow "I" to the reach and the discharge at B is the outflow "O" from the reach.

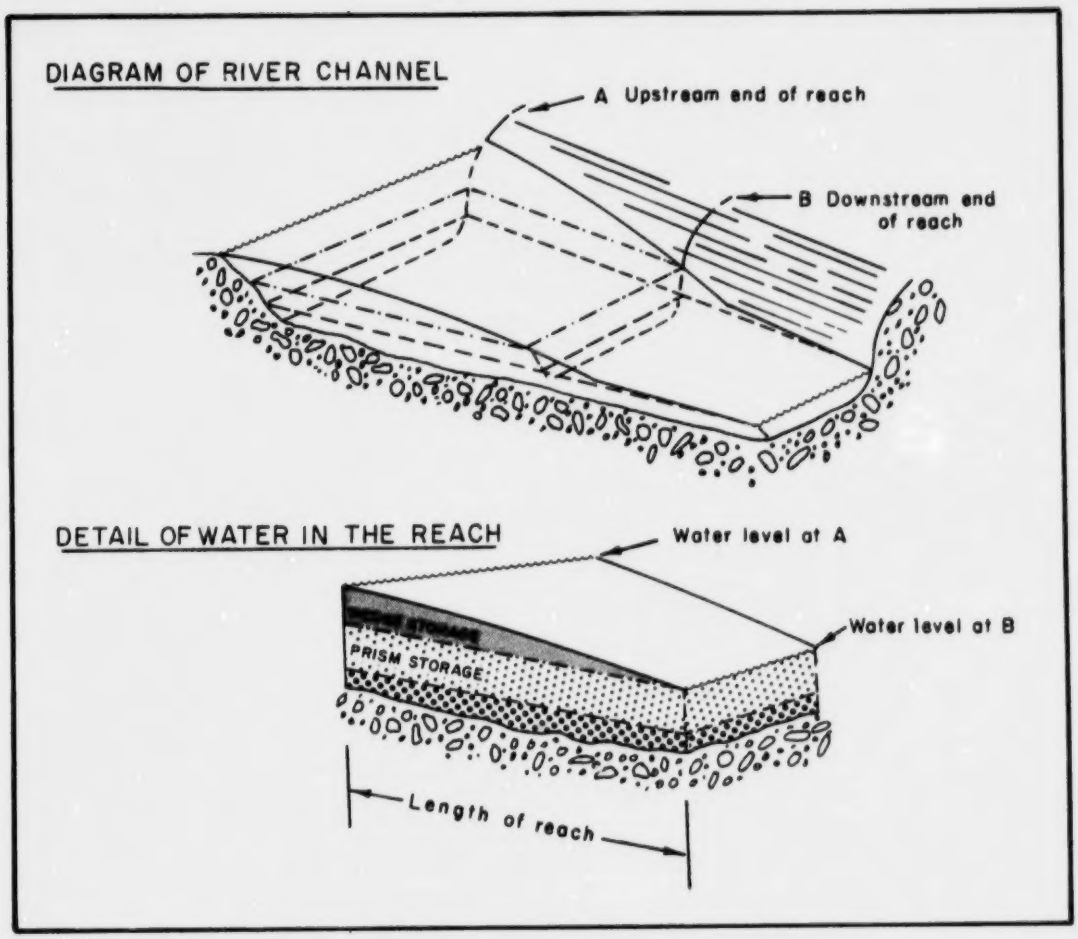


DIAGRAM OF RIVER CHANNEL
A Upstream end of reach
B Downstream end of reach
DETAIL OF WATER IN THE REACH
Water level at A
Water level at B
PRISM STORAGE
Length of reach

FIGURE 3.6: River Channel During Rising Stage

During the time period considered, the total inflow to the reach is:

$$\frac{(I_1 + I_2)\ t}{2}$$

and the total outflow is:

$$\frac{(O_1 + O_2)\ t}{2}$$

where:

t = Time period,

I_1 = Inflow at the beginning of the time period,

I_2 = Inflow at the end of the time period,

O_1 = Outflow at the beginning of the time period,

O_2 = Outflow at the end of the time period.

The above basic water balance equation can now be expressed in terms of inflows, outlfows, time period, and channel storage:

$$\frac{(I_1 + I_2)\, t}{2} - \frac{(O_1 + O_2)\, t}{2} = S_2 - S_1$$

where;

S_1 = Channel storage at the beginning of the time period,

S_2 = Channel storage at the end of the time period.

This is the basic storage equation for any water body and it is the basis for routing in lakes and reservoirs. This basic equation, in this form, cannot easily be used for river routing however, since it is difficult to measure storage, and thus the values of S_2 and S_1 are never known.

3.2.3.2 Derivation of the SSARR River Routing Equation

The basic storage equation is algebraically reorganized to provide a final SSARR river routing equation, where the storage/discharge relationship is defined by a parameter TS, termed "Time of Storage". This manipulation of the storage equation is shown below:

First replace the inflow term $\frac{I_1 + I_2}{2}$ by mean inflow "Im" and

replace the storage term $S_2 - S_1$ by change in storage "ΔS". Then the basic storage equation takes the form:

$$Im - \frac{O_1 + O_2}{2} = \frac{\Delta S}{t}$$

Next substract O_1 and rearrange as shown below:

$$Im - O_1 - \frac{O_1 + O_2}{2} = \frac{\Delta S}{t} - O_1$$

$$Im - O_1 = \frac{\Delta S}{t} - O_1 + \frac{O_1}{2} + \frac{O_2}{2}$$

$$Im - O_1 = \frac{\Delta S}{t} + \frac{(O_2 - O_1)}{2}$$

Multiply by: $\frac{t}{O_2 - O_1}$

$$\frac{(I_m - O_1)t}{(O_2 - O_1)} = \frac{\Delta S\,(t)}{t(O_2 - O_1)} + \frac{(O_2 - O_1)t}{2(O_2 - O_1)}$$

$$\frac{(I_m - O_1)t}{(O_2 - O_1)} = \frac{\Delta S}{O_2 - O_1} + \frac{t}{2}$$

Replace the term $(O_2 - O_1)$ by change in outflow "ΔO"

$$\frac{(I_m - O_1)t}{(O_2 - O_1)} = \frac{\Delta S}{\Delta O} + \frac{t}{2}$$

Let $TS = \frac{\Delta S}{\Delta O}$

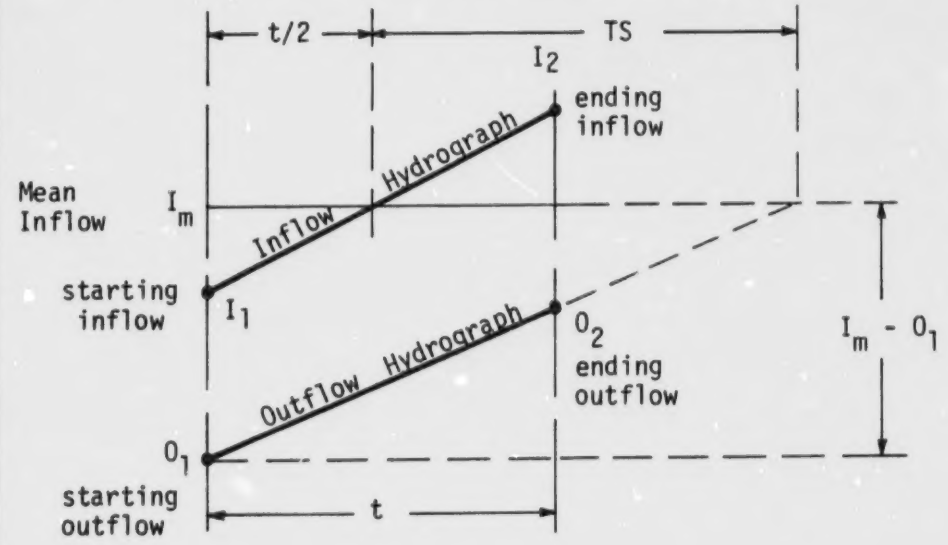
$$\frac{(I_m - O_1)t}{(O_2 - O_1)} = TS + \frac{t}{2}$$

$$\frac{(I_m - O_1)t}{TS + \frac{t}{2}} = O_2 - O_1$$

$$\frac{(I_m - O_1)t}{TS + \frac{t}{2}} + O_1 = O_2$$

The final equation above is the SSARR routing equation. This equation is used for the REACH routing operation in SIMPAK. This equation is shown in geometric form in Figure 3.7.

This is a graphical representation of the SSARR routing equation, as used by operation REACH in SIMPAK. It represents an increment of the hydrograph for a single time period of routing.



The SSARR routing equation is: $O_2 = \frac{(I_m - O_1)t}{TS + t/2} + O_1$

FIGURE 3.7: SSARR Routing Equation Diagram

3.2.3.3 Time of Storage

To derive this routing equation a new term (TS) was introduced to replace $\Delta S/\Delta O$. Note that this term has the dimensions of time. The hydraulic significance of this term is equivalent to the storage/discharge relationship that is used in lake and reservoir routing; in other words, a function defining TS varying with discharge is equivalent to a storage/discharge function. The SSARR routing method allows two approaches to the definition of TS for reach routing. These are both allowed in the REACH operation;

(a) TS is normally computed in the REACH operation by the equation:

$$TS = \frac{KTS}{Q^n}$$

where:

KTS is an arbitrary constant proportional to a flood wave's time of travel through a reach, n is a calibrating parameter that allows TS to vary with discharge at different rates (usually falls in the range 0.1 to 0.3 for western Canadian streams).

(b) If a more complex TS relationship is necessary to calibrate a reach, tables of TS versus discharge may be specified for the reach. These tables are input, under the relevant station number, in a tables data file. The absence of a KTS value in the PAR 2 field of the REACH operation card signals the use of the table method. Then, whenever a TS value is needed in the routing equation, it is found from the table of TS versus discharge.

It can be shown that TS is equal to the wave time of travel of a flood wave through the reach. (W.T. Wilson, 1941).

This is a very useful characteristic of TS, as it allows a starting estimate of TS for calibration purposes.

3.2.3.4 Mode of Operation of REACH

The REACH operation in the SIMPAK program operates the same way as the basic river routing in the SSARR program. In this method, each reach of river channel is considered to be made up of several sub-reaches called "phases" or "increments". Each increment acts as a small lake according to the basic routing equation. For each increment an average inflow is computed. The starting outflow for each increment is the ending outflow from the previous routing period for that increment. Also, the outflow from one increment is the inflow for the next (downstream) increment. Thus, each river reach in the Yukon Basin Model is made up of several sub-reaches or increments where an individual routing computation is carried out for each increment.

The routing time period "t" for the routing equation must always be smaller than twice TS. The SIMPAK program operates on a fixed time period of twenty-four hours. If TS is less than twelve hours in any routing computation, the routing period within the REACH operation is sub-divided as often as necessary to make "t" smaller than 2(TS). Results of this computation, however, are printed only for the end of the twenty-four hour period.

The REACH operation considers the routing time period to begin at noon on the previous day and end at noon the current day of simulation. The mean daily inflow to the reach the previous day is considered to be the starting inflow (see Figure 3.7) and the mean daily inflow the current day is considered to be the ending inflow; the mean inflow to the reach I_m is the average of these two. The

ending outflow values are considered to be mean daily outflows from the reach. The ending outflow from the last increment is the mean daily outflow from the river reach.

Each REACH operation requires initial values for the starting inflow (i.e. the previous day's mean inflow to the reach) and the starting outflow (i.e. the previous day's mean outflow from the reach). If these are not specified in the model control cards, they are computed so that starting outflow equals starting inflow, and starting inflow is extrapolated backward from the first two days' inflows. Starting inflows for each increment within the reach are interpolated between the starting inflow and starting outflow. The starting outflows for increments within the reach are also interpolated on the first day of the simulation and are carried forward from day to day through the simulation.

3.2.3.5 Calibrating the REACH Operation

In calibrating a REACH operation three parameters can be varied. These are:

NPS ... the number of phases or increments within the reach
n ... the value of the exponent of discharge in the TS equation
KTS ... constant in the TS equation (varies directly with TS).

The effects of varying these parameters are illustrated in Figures 3.8 to 3.12. Note that in all of these figures TS is computed as hours per phase.

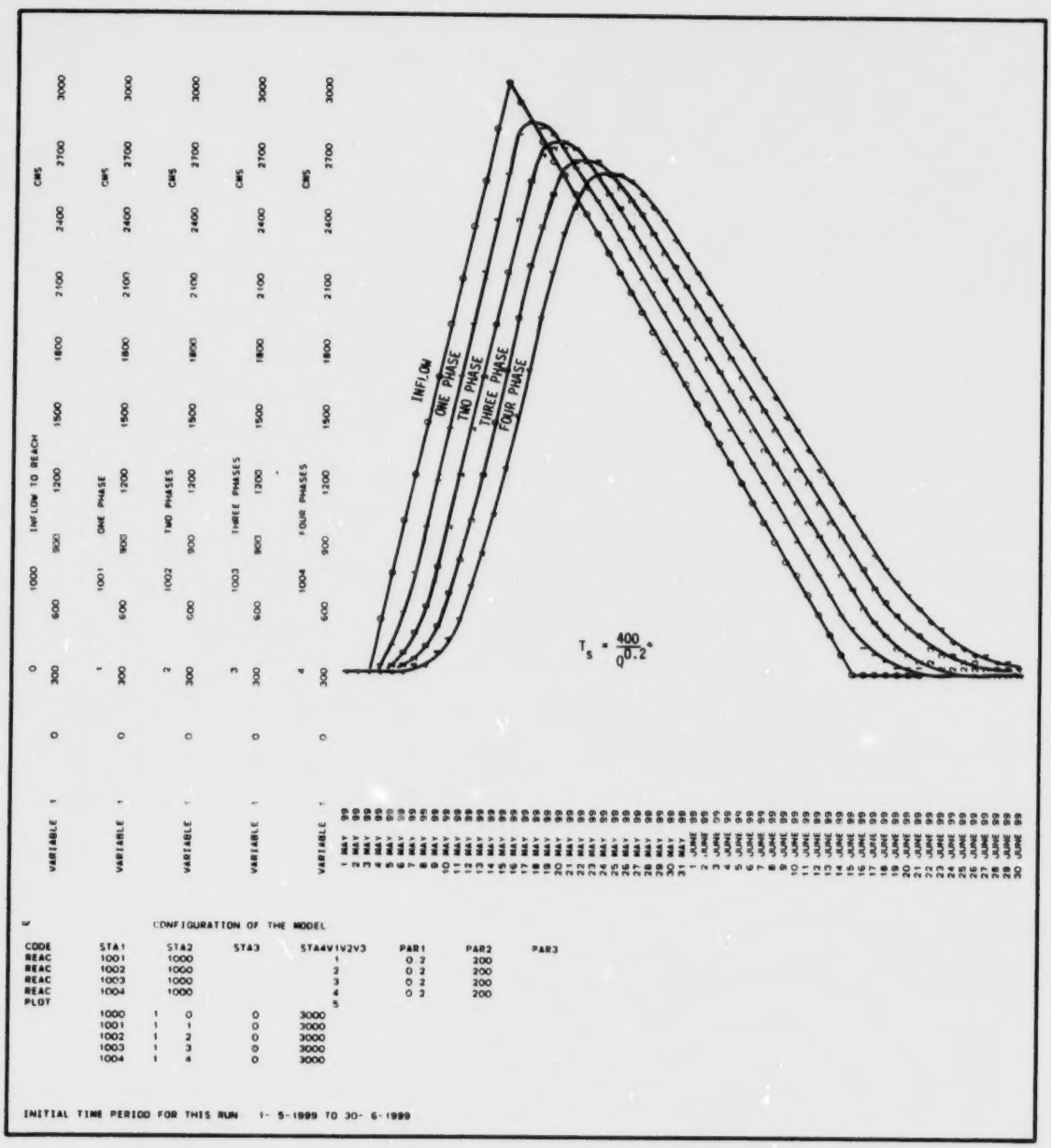


FIGURE 3.8: REACH Operation, Effect of Varying Number of Phases

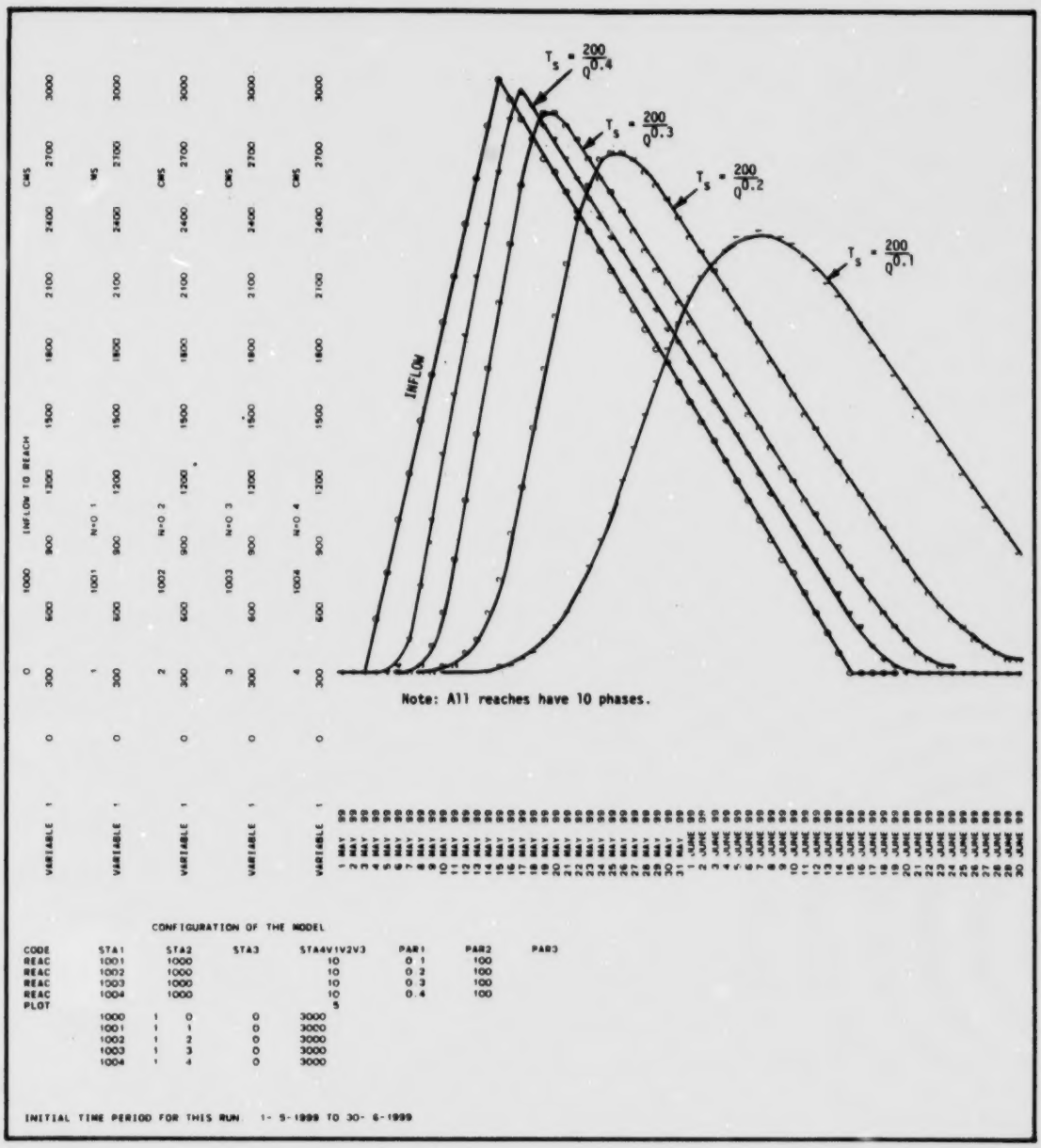

$T_s = \frac{200}{Q^{0.4}}$
$T_s = \frac{200}{Q^{0.3}}$
$T_s = \frac{200}{Q^{0.2}}$
$T_s = \frac{200}{Q^{0.1}}$
INFLOW
Note: All reaches have 10 phases.
CONFIGURATION OF THE MODEL
INITIAL TIME PERIOD FOR THIS RUN 1- 5-1999 TO 30- 6-1999

FIGURE 3.9: REACH Operation, Effect of Varying n Value

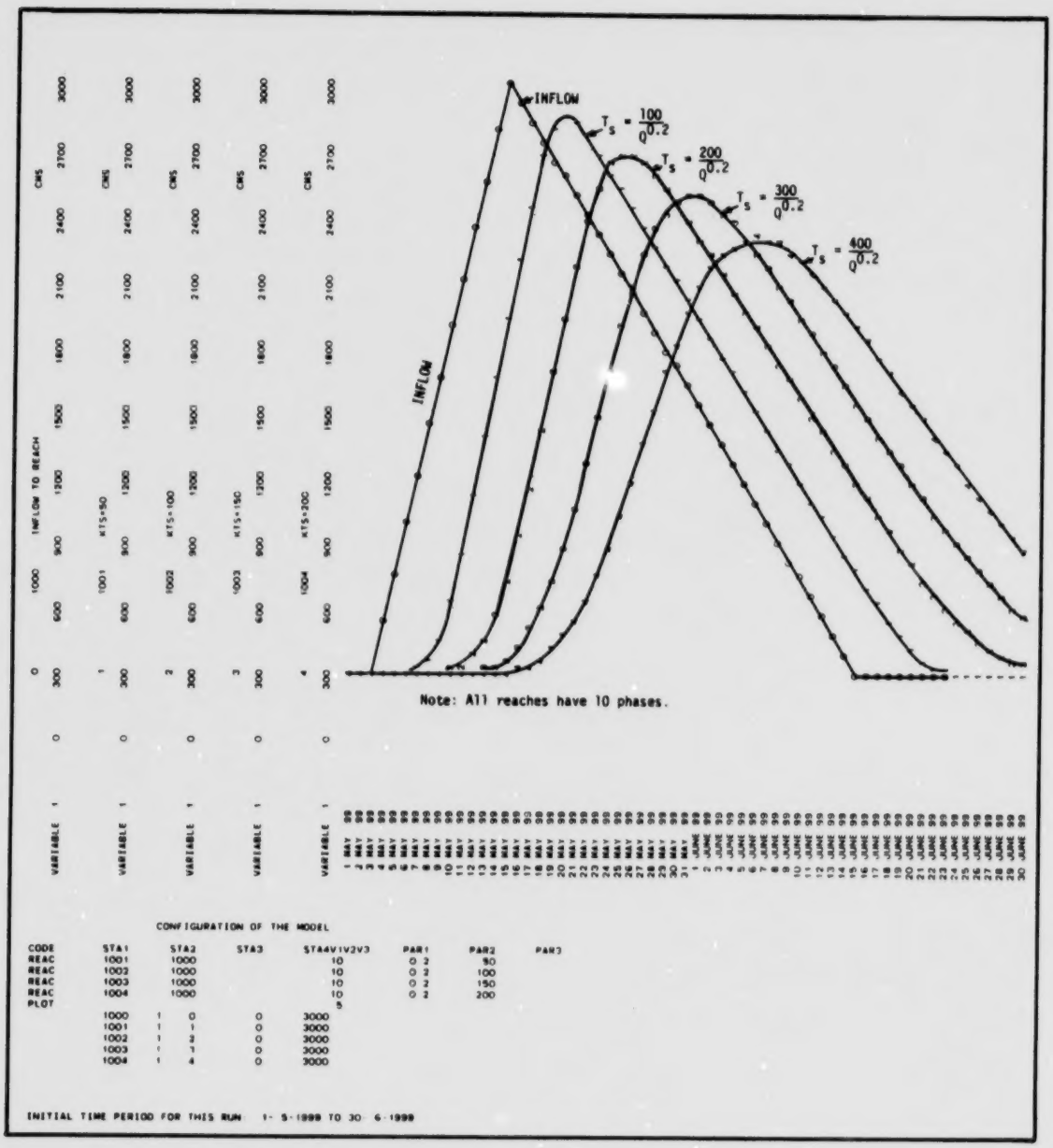

INFLOW
$T_s = \frac{100}{Q^{0.2}}$
$T_s = \frac{200}{Q^{0.2}}$
$T_s = \frac{300}{Q^{0.2}}$
$T_s = \frac{400}{Q^{0.2}}$
Note: All reaches have 10 phases.
CONFIGURATION OF THE MODEL
INITIAL TIME PERIOD FOR THIS RUN 1- 5-1999 TO 30 6-1999

FIGURE 3.10: REACH Operation, Effect of Varying KTS Value

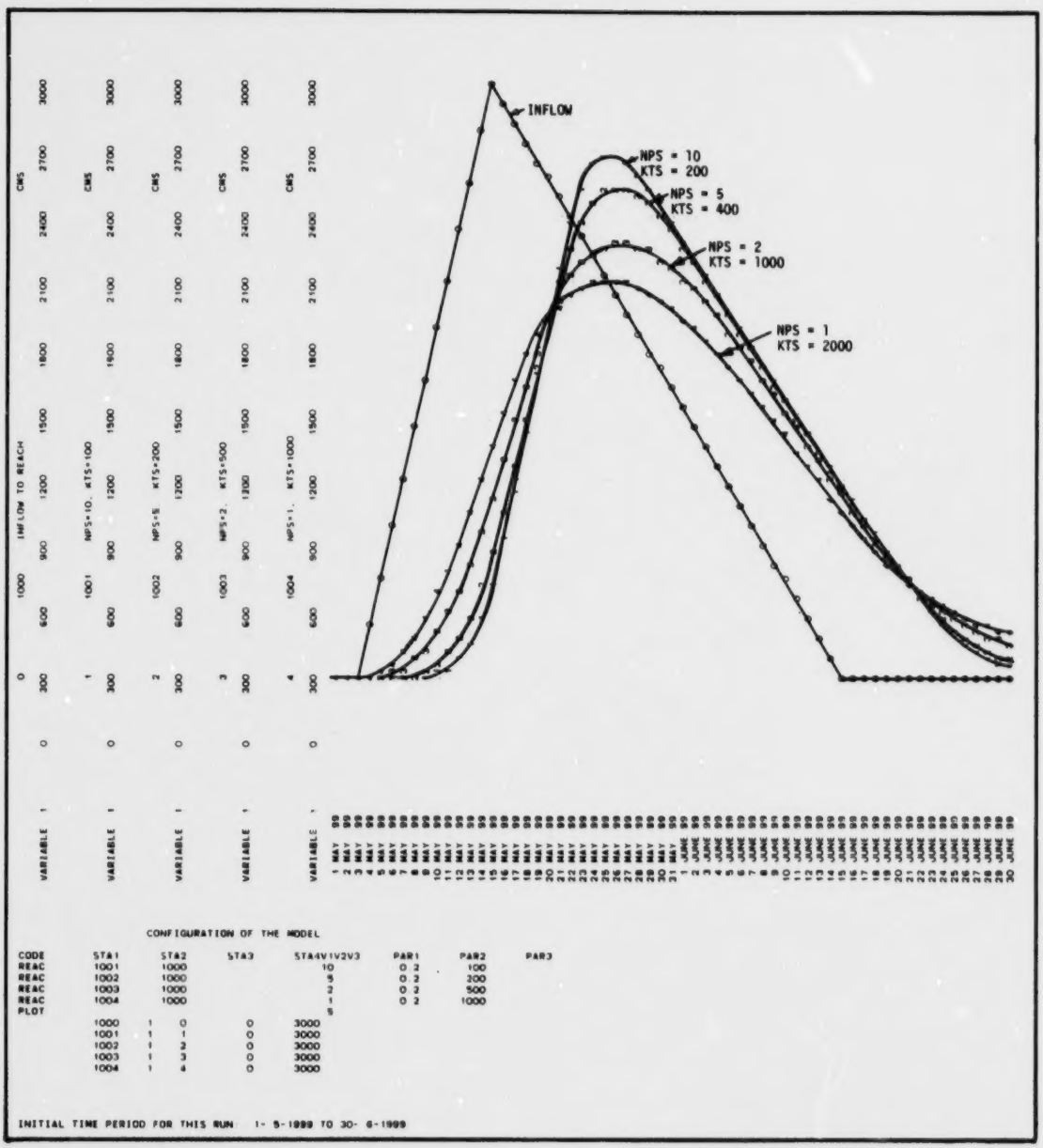


FIGURE 3.11: REACH Operation, Effect of Varying NPS and KTS for Constant Time-of-Storage

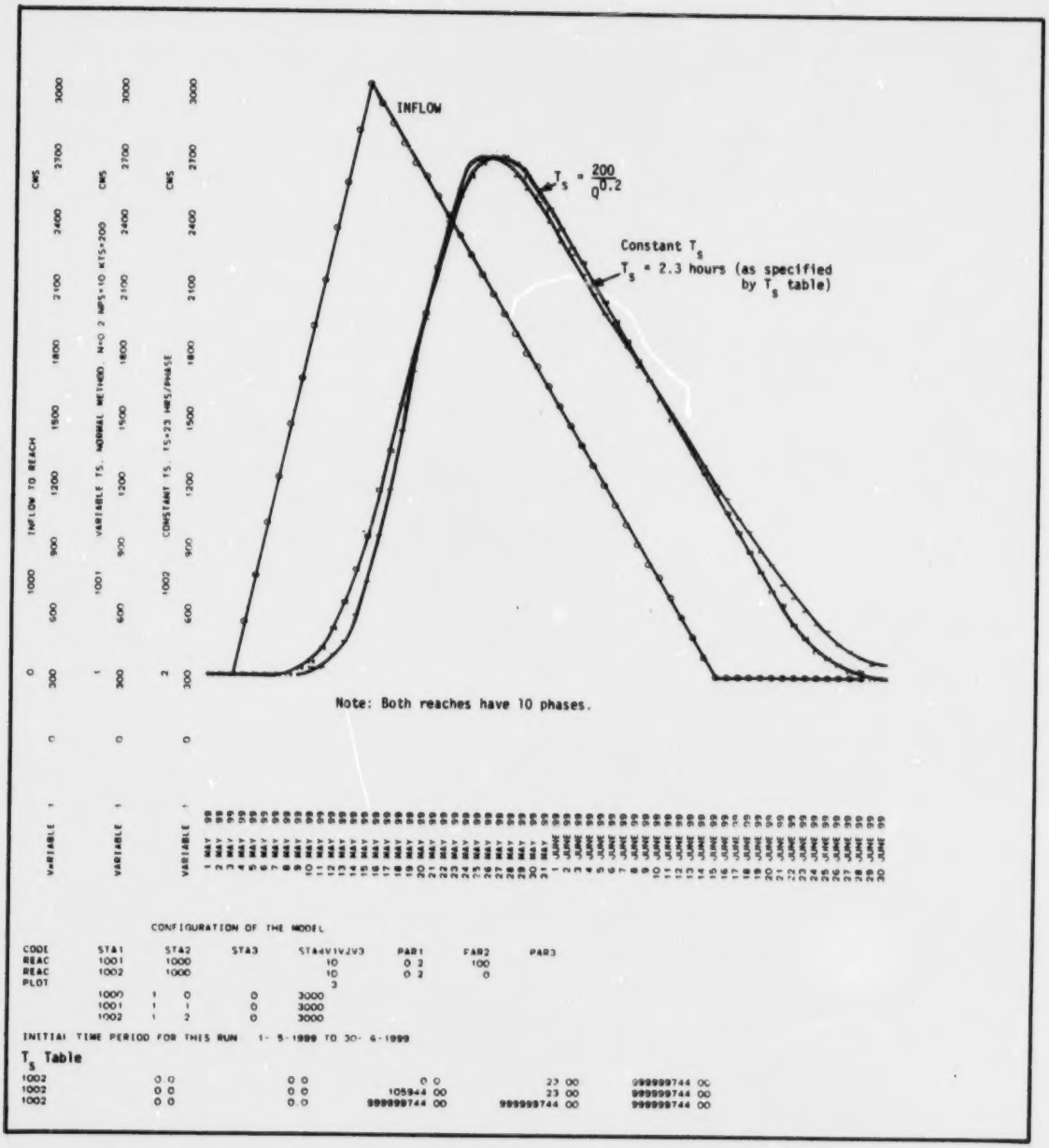

INFLOW
$T_s = \frac{200}{Q^{0.2}}$
Constant T_s
T_s = 2.3 hours (as specified by T_s table)
Note: Both reaches have 10 phases.
CFS
INFLOW TO REACH
VARIABLE TS. NORMAL METHOD. N=0 2 HPS=10 KTS=200
CONSTANT TS. 15=23 HRS/PHASE
VARIABLE 1
CONFIGURATION OF THE MODEL
CODE ST&1 ST&2 ST&3 ST&4V1V2V3 PAR1 PAR2 PAR3
REAC 1001 1000 10 0 2 100
REAC 1002 1000 10 0 2 0
PLOT 3
1000 1 0 0 3000
1001 1 1 0 3000
1002 1 2 0 3000
INITIAL TIME PERIOD FOR THIS RUN 1- 5-1999 TO 30- 6-1999
T_s Table
1002 0 0 0 0 0 0 23 00 999999744 00
1002 0 0 0 0 0 105944 00 23 00 999999744 00
1002 0 0 0 0 0 999999744 00 999999744 00 999999744 00

FIGURE 3.12: REACH Operation, Comparison of Variable and Constant Time-of-Storage

There are two methods generally accepted for calibrating the REACH operations;

(a) compute the parameters from observed travel time on the river,
(b) determine the parameters by trial and error fitting of the observed flows.

Method (a) was not used in this study except for initial estimates. Method (b), used in this study, has been used previously by the U.S. Corps of Engineers in calibrating their SSARR models for the Columbia River. The following pages describe method (b).

The reach is first divided into several increments mainly on the basis of the judgement of the hydrologist. For fast flowing rivers several short increments would be selected while for broad, slow rivers, one increment might cover thirty miles of river.

Next a value for the exponent n is selected, again mainly on the basis of experience and judgement. A value of 0.2 has been found to apply best to most mountainous rivers in the Pacific Northwest area.

Knowing values of NPS and n, a value of KTS for each increment is computed based upon an estimate of the travel time of the river. The travel time may be determined by observing dye movement or by a knowledge of the river velocities, but often it is simply estimated from examination of gauged flows at various points along the river.

The total travel time is first divided by the number of increments selected for the reach giving the travel time per increment. The required KTS value to fit all the other selected parameters is computed from the routing equation:

$$TS = \frac{KTS}{Q^n}$$

$$\text{Therefore } KTS = TS \times Q^n$$

This is easily solved by a calculator or it may be solved using a chart such as that shown in Figure 3.13.

These make up an initial estimate for the parameters and are used in a first trial of the routing operation. An example is shown below:

For Stewart River branch the approximate distances from
- Mayo to Stewart Crossing is 50 km
- Stewart Crossing to McQuesten is 55 km
- McQuesten to Yukon River is 130 km

Using a distance of 26.5 km for each phase, the following is approximated:
- two phases for Mayo to Stewart Crossing
- two phases for Stewart Crossing to McQuesten
- five phases for McQuesten to Yukon River

In 1980, the peak flow travelled at a velocity of about 9 km per hour from Mayo to Stewart River at mouth. The travel time for each phase is

$TS = 26.5 / 9 = 2.94$ hours

Assuming an n value of 0.2 and a representative discharge of 1930 cms, then:

$KTS = TS \times Q^n = 2.94 \times (1930)^{0.2} = 13.36$

Note that the KTS computed is in metric units.

Two or three representative sets of flow records for the river are selected, representing typical flow conditions on the river for the range of flows to be simulated. These form the test data along with any flow records available for the period from inflowing local tributaries.

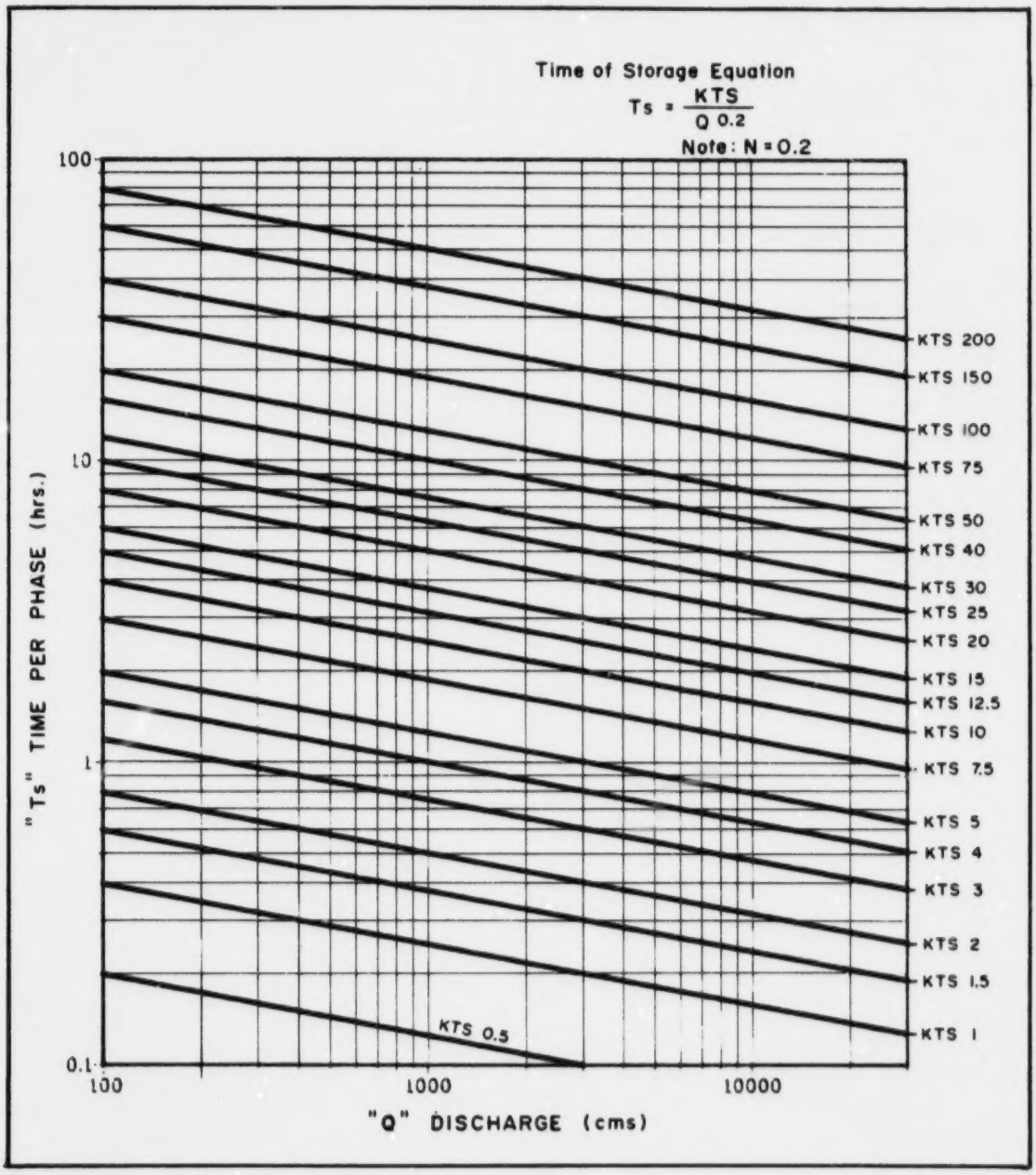


FIGURE 3.13: Chart of KTS versus Discharge and Time-of-Storage

A test model for all reaches between two gauge points on the river is now made up. This model is set up to take the upstream gauged flows, route them through the reaches as far as the next downstream gauge point. There, the routed flows are subtracted from the gauged flows giving flow values that represent the local inflows to the river over that reach. The hydrographs for the inflow to the reach, the routed flows, the computed local flows, and observed local streams are all plotted on one plot. At this stage the calibration can be checked by two indicators:

i) the shape of the routed hydrograph compared to the shape of the observed hydrograph
ii) the shape and timing of the computed local inflows compared to any measured inflowing streams.

The shape of the routed hydrograph will always be quite similar to that of the observed hydrograph except for the influence of the inflowing streams, and for that reason the precision of the calibration is difficult to measure from it. The shape of the computed local hydrograph, however, is very sensitive to slight changes in the routing parameters for the reach. By varying the parameters as necessary to slow down or speed up the routing (KTS and n), the peaks of the computed local hydrograph can be brought into line with the observed local flows. By varying the parameters to give more sensitive or peaky routing (NPS) the shape of the computed local hydrographs can be varied. By several trials in this manner, using the test results in Figures 3.8 through 3.12 as a guide, an optimum calibration can be reached.

An illustration of this model of calibration is provided in the hydrograph shown in Figure 3.14.

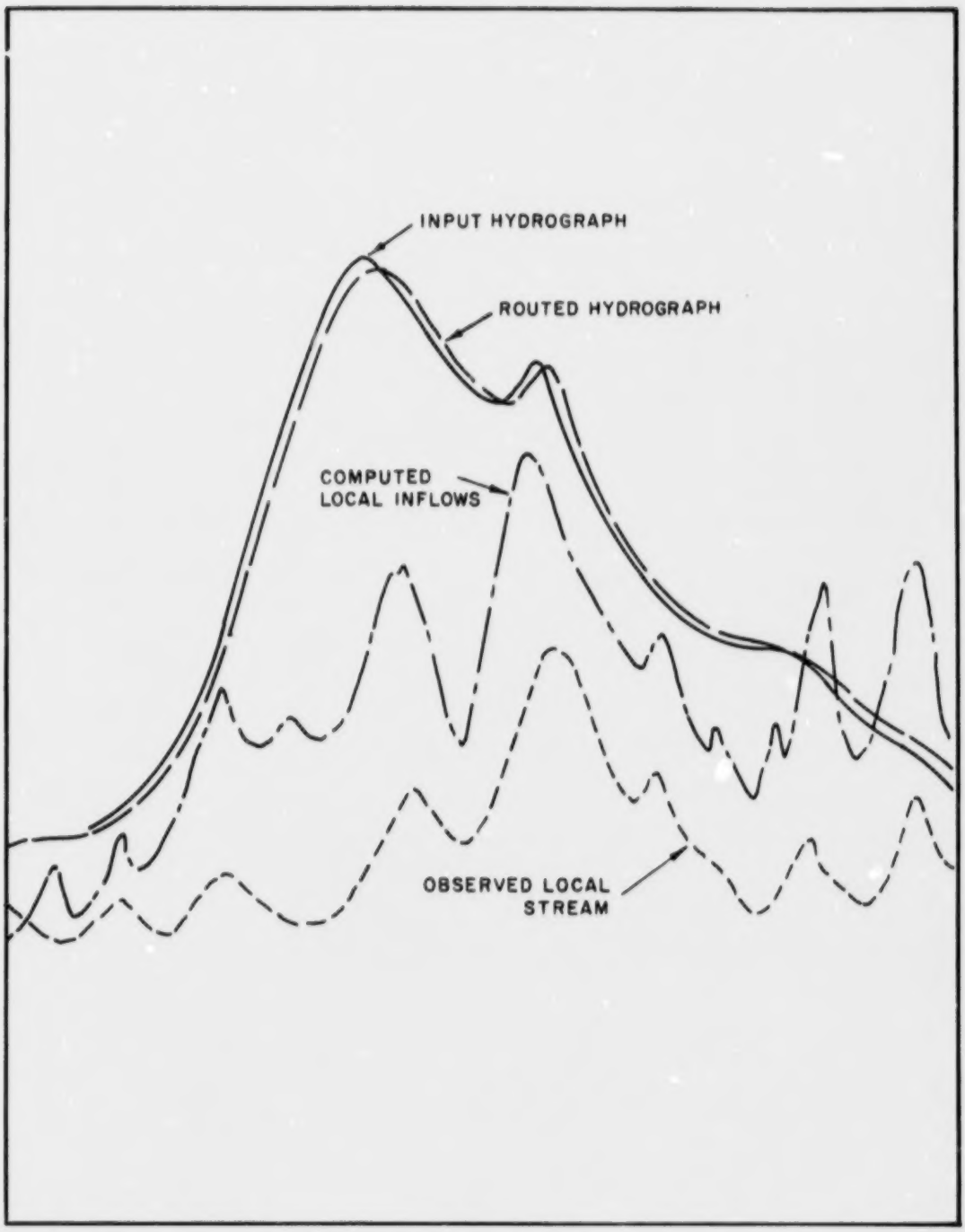


FIGURE 3.14: Illustration of REACH Calibration (Trial Method)

3.3 Revisions to a Model

The Yukon Basin Model discussed in this report simulates the Yukon River system in its present form, i.e. with existing projects in place. Other proposed projects in the system can be simulated by making minor changes to the model and the data input to it.

To simulate a proposed project in the system, the project must be inserted into the model at the proper place. This involves changes to the input model control data and possibly to the tables data and hydrologic data as well. Such changes usually involve adding a tributary to the model, changing the characteristics of a node in the model or replacing a reach routing operation with one or more different operations. This section outlines the normal procedures for making such changes.

3.3.1 Adding a Tributary Branch

If a project to be tested is located on an upstream portion of a tributary that has not been modelled in the Yukon Basin Model, then a new portion of a model must be set up to simulate the tributary including the project, and this new portion must be inserted into the existing model.

First the tributary model must be formulated and calibrated, then the tributary model can be inserted into the main model. To illustrate the procedure an example is used here.

For this example the same hypothetical basin shown in Figure 2.1 is used except that a reservoir located on the West River is added. The new configuration, including the West River model, is illustrated on the map shown in Figure 3.15 and on the schematic diagram shown in Figure 3.16.

By comparing with Figure 2.1, it can be seen that the addition of the West River branch is accomplished simply by replacing

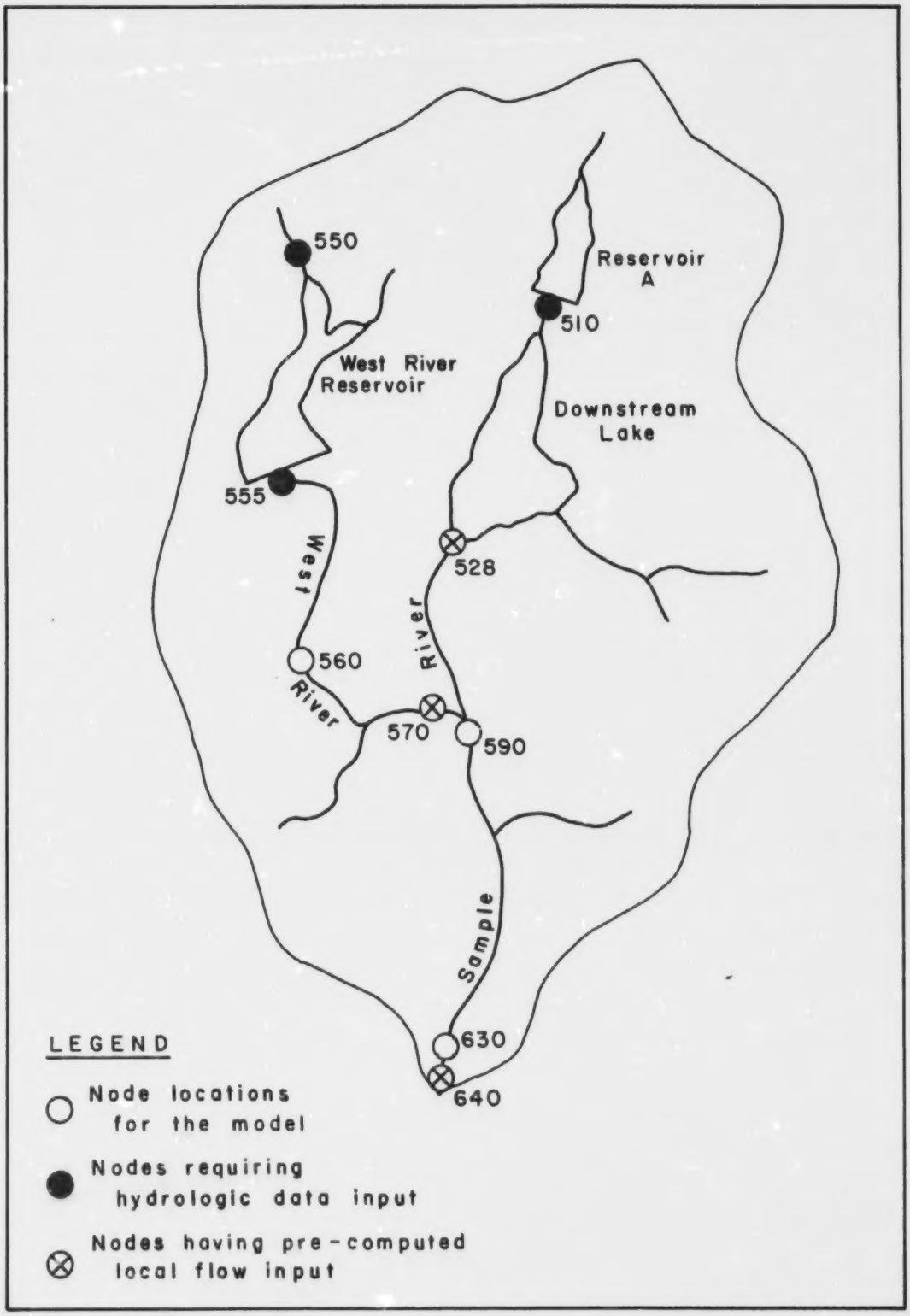


FIGURE 3.15: Map of Area of Sample Model Adding a Tributary Branch

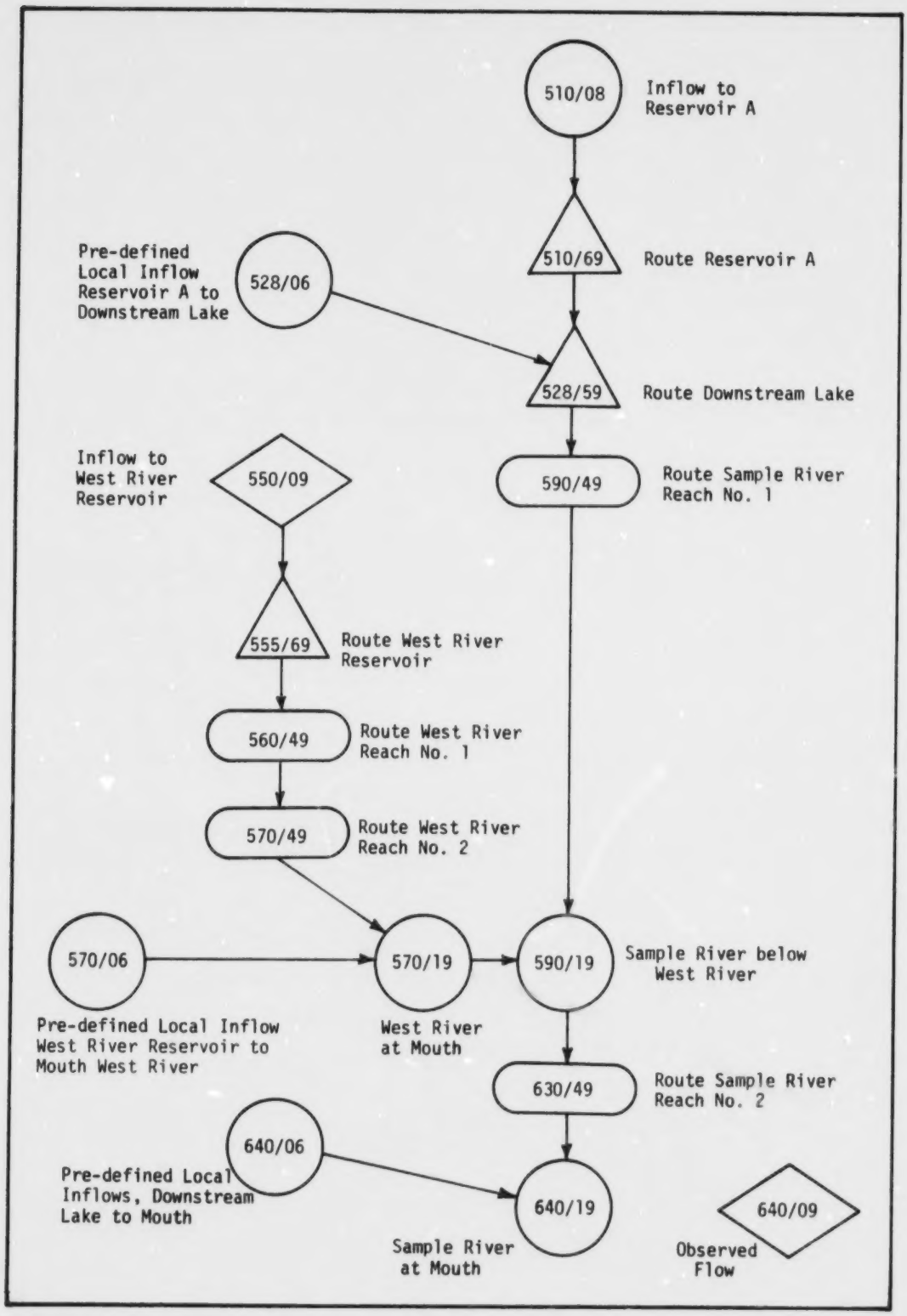


FIGURE 3.16: Flow Chart of Sample Model Adding a Tributary Branch

one node of the model with the whole of the West River model segment. Likewise, in the model control instructions, the branch can be added by inserting in the operations list of the model control instructions the operations to accomplish the modelling of the branch. These operations are:

```
RESE        55569       55009
REAC        56049       55569
REAC        57049       56049
ADD         57019       57049       57006
```

These instructions can be inserted in the operations list anywhere above the operation "ADD 59019". The stations required for the branch must also be added to the stations list in the model control data and any tables or hydrometric data required for the branch must be added to the tables and data files. Next all references to station 57009 in the operation list must be replaced by the station number 57019 to complete the conversion of the model. The new model is illustrated by the new control data shown in Figure 3.17. This can be compared to the original control data shown in Figure 2.3.

Note that a similar conversion would have to be made to the local flow model in order to compute the local flow 57006. In the local model, if the reservoir were not already in existence, a reach of river would replace the reservoir. The addition to the local model would take the form:

```
REAC        55549       55009
REAC        56049       55549
REAC        57049       56049
SUBT        57006       57009       57049
FILE (or WLNR)  57006
```

Here the observed upstream flow was routed through three reaches, one of which is replaced by the reservoir in the project model, and the resulting routed flow is subtracted from the downstream observed flow to get the local. The local flow is then filed to a SSARR file with a "FILE" operation (or

```
SAMPLE MODEL ADDING A TRIBUTARY BRANCH
       51008          1      INFLOW TO RESERVOIR A
       51069          9 1    RESERVOIR ROUTE, RESERVOIR A
       52806          1      PRE-DEFINED LOCAL INFLOW, RES A TO DWST LAKE
       52859          9 1    LAKE ROUTE, DOWNSTREAM LAKE
       59049          1      ROUTE SAMPLE RIVER, REACH NO. 1
       55009          1      INFLOW TO WEST RIVER RESERVOIR
       55569          9 1    RESERVOIR ROUTE, WEST RIVER RESERVOIR
       56049          1      ROUTE WEST RIVER, REACH NO. 1
       57049          1      ROUTE WEST RIVER, REACH NO. 2
       57006          1      PRE-DEFINED LOCAL INFLOWS, W.R. RES. TO MOUTH WEST RIVER
       57019          1      PROJECT FLOWS, WEST RIVER AT MOUTH
       59019          1      PROJECT FLOWS, SAMPLE RIVER BELOW WEST RIVER
       63049          1      ROUTE SAMPLE RIVER, REACH NO. 2
       64006          1      PRE-DEFINED LOCAL INFLOW, DWST LAKE TO MOUTH
       64019          1      PROJECT FLOWS, SAMPLE RIVER AT MOUTH
       64009          1      OBSERVED FLOWS, SAMPLE RIVER AT MOUTH
$END
1  5 1980  31  7 1980      0    2    1    0    0    0    1    2    1
RESEV      51069      51008          -999999999 1 9 9  315770.
LAKE       52859      51069     52806                      56.63
REACH      59049      52859                          2        0.2       19.0
RESEV      55569      55009          -999999999 4 9 9  825000.
REACH      56049      55569                          3        0.2       10.0
REACH      57049      56049                          1        0.2       28.0
ADD        57019      57049     57006                1
ADD        59019      59049     57019                1
REACH      63049      59019                          2        0.2       22.0
ADD        64019      63049     64006                1
PLOT                                                 2
           64019      1    C        0       5000
           64009      1    N        0       5000
$END
$END
```

FIGURE 3.17: SIMPAK Input Control Data for Sample Model Adding a Tributary Branch

alternatively can be written to a long record file with a WLNR operation). The local flow can then be read later by a project model.

3.3.2 Inserting a Project at a Node

In the previous section, it was seen how a tributary branch could be added to a model by simply replacing one node of the model with a sub-model representing the branch. Inserting a project at an existing node in a model is a similar procedure. In this case the operation for that node is changed to account for the project. Depending upon the extent of the project, (e.g. the distance upstream that would be flooded by a reservoir) other nodes might also have to be revised.

Again an example is used to illustrate the procedure. The same hypothetical basin as shown in Figure 2.1 is used, except in this case a reservoir has been added at location 590 in the basin, so that both the outflow from Downstream Lake and from station 57009 "West River" flow into the reservoir. The reservoir in this example effectively floods the whole of the reach that is modelled by station 59049. The new situation is illustrated in the map of Figure 3.18.

This addition is easily handled by replacing the ADD operation at location 590 with a RESEV operation.

The schematic diagram for the revised model is shown in Figure 3.19 and the revised control data are listed in Figure 3.20. By comparing these with the original model shown in Figures 2.2 and 2.3 it can be seen that both the "REACH 59049" operation and the "ADD 59019" operation were replaced by the RESEV operation:

```
RESEV       59069       52859       57009
```

To complete the description of the reservoir, the following additional actions must be taken;

- the VAR and PAR fields of the operation cards are filled in with the required data,
- a station card for station 59069 is inserted in the station card list,
- a table defining the elevation/storage/maximum discharge relationships for the reservoir must be added to the tables data file (note that the maximum discharge part of the table is optional), and
- the control data that defines the regulation pattern of the reservoir is included in one of the input hydrologic data files.

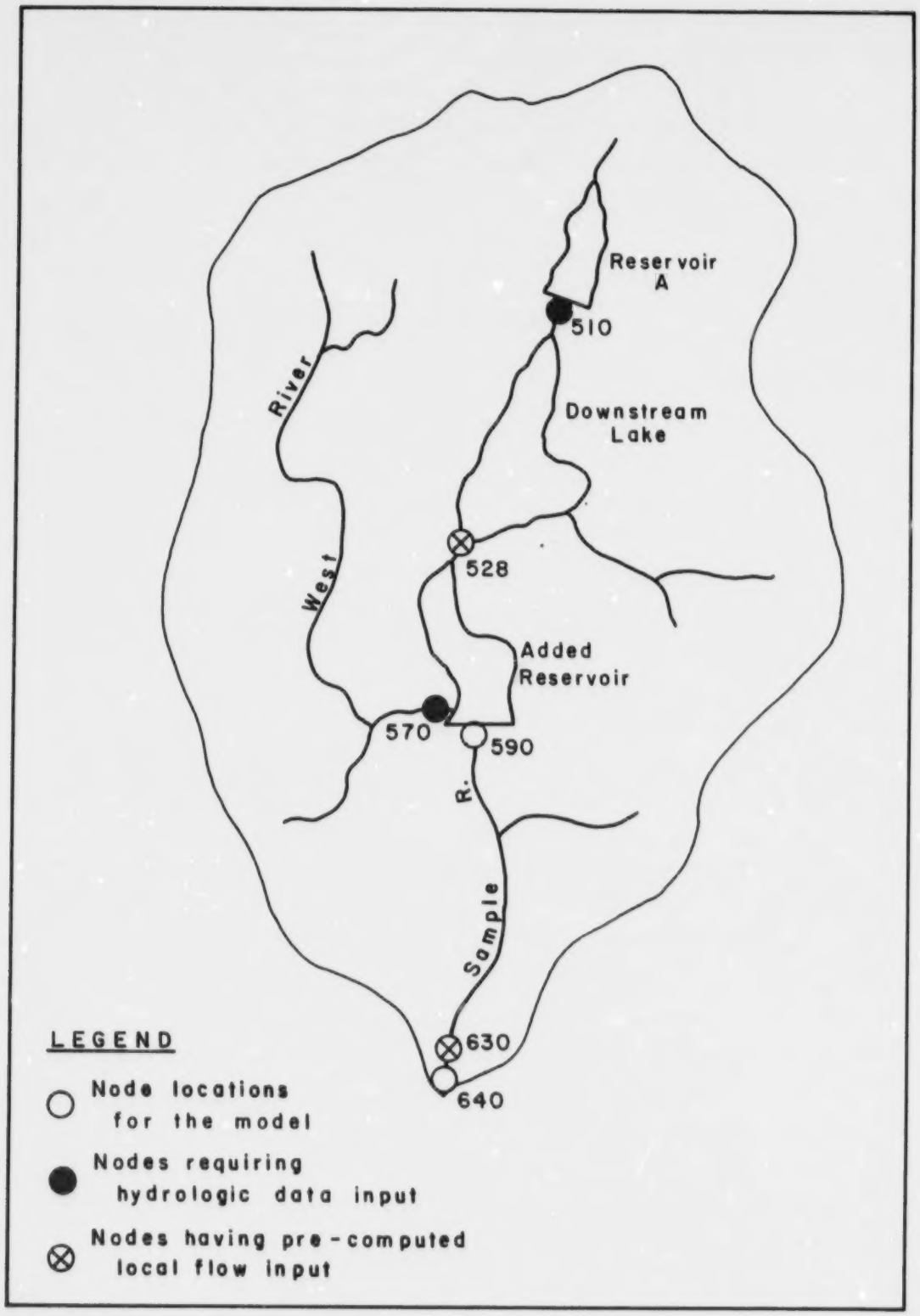


FIGURE 3.18: Map of Area of Sample Model Adding a Project at a Node

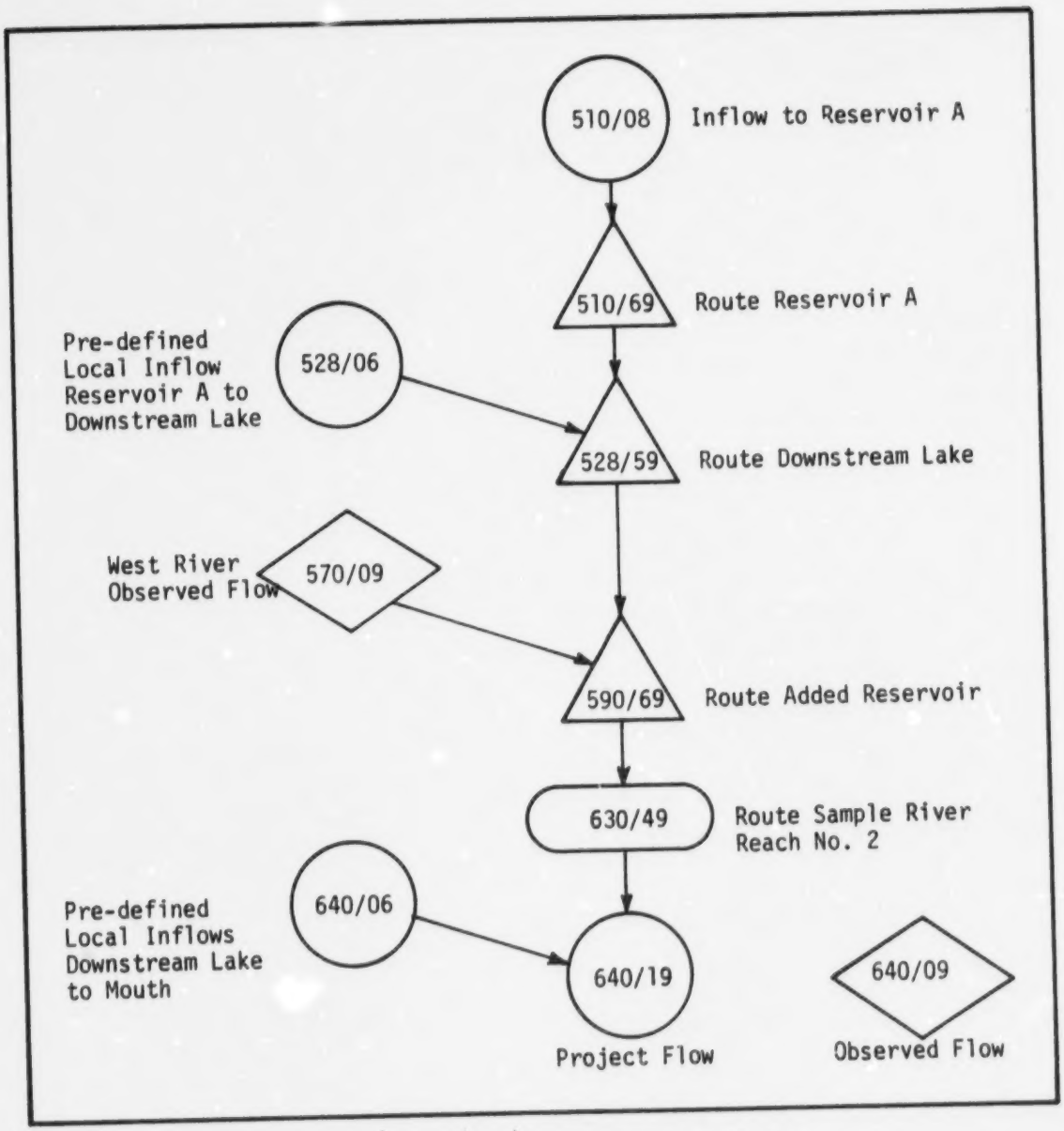


FIGURE 3.19: Flow Chart of Sample Model Adding a Project at a Node

```
SAMPLE MODEL, ADDING A PROJECT AT A NODE
       51008          1      INFLOW TO RESERVOIR A
       51069          9 1    RESERVOIR ROUTE, RESERVOIR A
       52806          1      PRE-DEFINED LOCAL INFLOW, RES A TO DWST LAKE
       52859          9 1    LAKE ROUTE, DOWNSTREAM LAKE
       59069          9 1    RESERVOIR ROUTE ADDED RESERVOIR
       57009          1      WEST RIVER OBSERVED FLOW
       63049          1      ROUTE SAMPLE RIVER, REACH NO. 2
       64006          1      PRE-DEFINED LOCAL INFLOW, DWST LAKE TO MOUTH
       64019          1      PROJECT FLOWS, SAMPLE RIVER AT MOUTH
       64009          1      OBSERVED FLOWS, SAMPLE RIVER AT MOUTH
$END
1  5 1980  31  7 1980      0    2    1    0    0    0    1    2    1
RESEV      51069     51008          -999999999 1 9 9  315770.
LAKE       52859     51069     52806                     56.63
RESEV      59069     52859     57009-999999999 1 9 9  962000.
REACH      63049     59069                    2          0.2       22.0
ADD        64019     63049     64006          1
PLOT                                          2
           64019     1    C         0       5000
           64009     1    N         0       5000
$END
$END
```

FIGURE 3.20: SIMPAK Input Control Data for Sample Model Adding a Project at a Node

This example was a simple replacement of operations. If the reservoir did not cover all of the reach 59049, then the REACH 59049 operation would have to be modified and retained and the configuration of the model would look like this:

RESEV	51069	51008	
LAKE	52859	51069	52806
REACH	54049	52859	
RESEV	59069	54049	57009
REACH	63049	59069	
ADD	64049	63049	64006

In this case, the REACH operation would be modified in the manner described in Section 3.3.3.

3.3.3 Inserting a Project Within a Reach

In the examples discussed in Sections 3.3.1 and 3.3.2, projects were inserted into a model by replacing nodes in the model. In these examples, no changes were made to any of the existing nodes. In many cases it is necessary to modify the characteristics of an existing node in the model to simulate the effect of a project. For example, a reservoir that extends only part way along a reach of the model would not replace the whole of the reach but only part of it leaving a partial routing effect for that reach. In such a case the REACH operation should be retained but the routing parameters for the reach should be modified to account for the change. Another example would be where a diversion was to be added in the middle of a reach and the routing operations would have to be split into two; one above and one below the diversion.

To illustrate such a situation, an example similar to that shown in Figure 3.18 is used, except that in this case the reservoir does not flood the whole of the reach between locations 528 and 590, but only floods the bottom third of the reach. This situation is shown in the map of Figure 3.21 and the model schematic diagram of Figure 3.22. Now, instead of the whole reach, only one-third has been lost to the reservoir. A reach having the effect of two-thirds of the former reach (operation 59049 of Figures 2.2 and 2.3) must be included in the model between "Downstream Lake" and "Added Reservoir". Some judgement is required in determining the characteristics of this revised reach.

The reach can be modified most easily by considering the time of storage TS. In the original reach there were two phases of routing each having a KTS value of 19.0 and an n value of 0.2. The total time of storage for that reach is computed as follows:

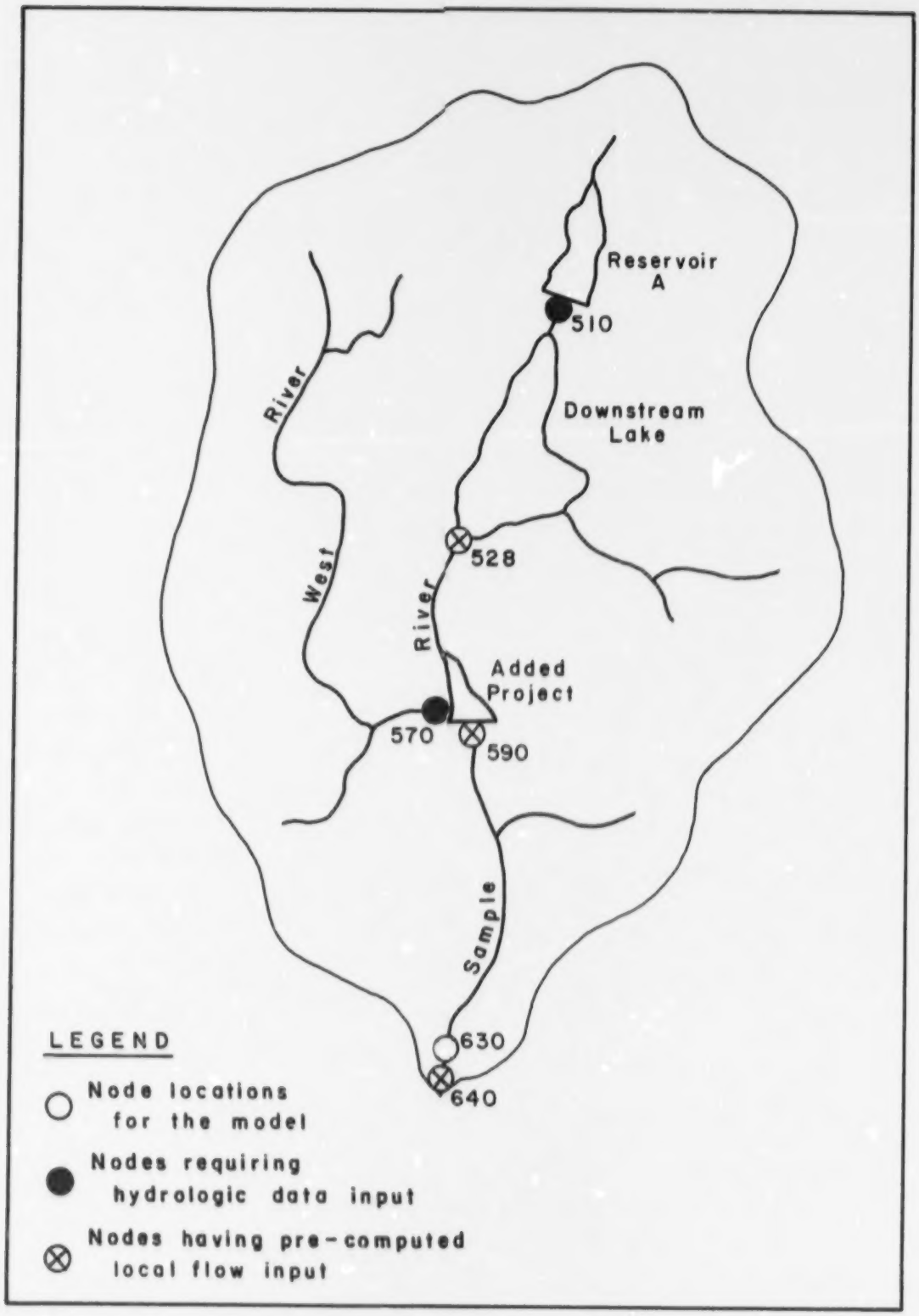


FIGURE 3.21: Map of Area of Sample Model Inserting a Project Within a Reach

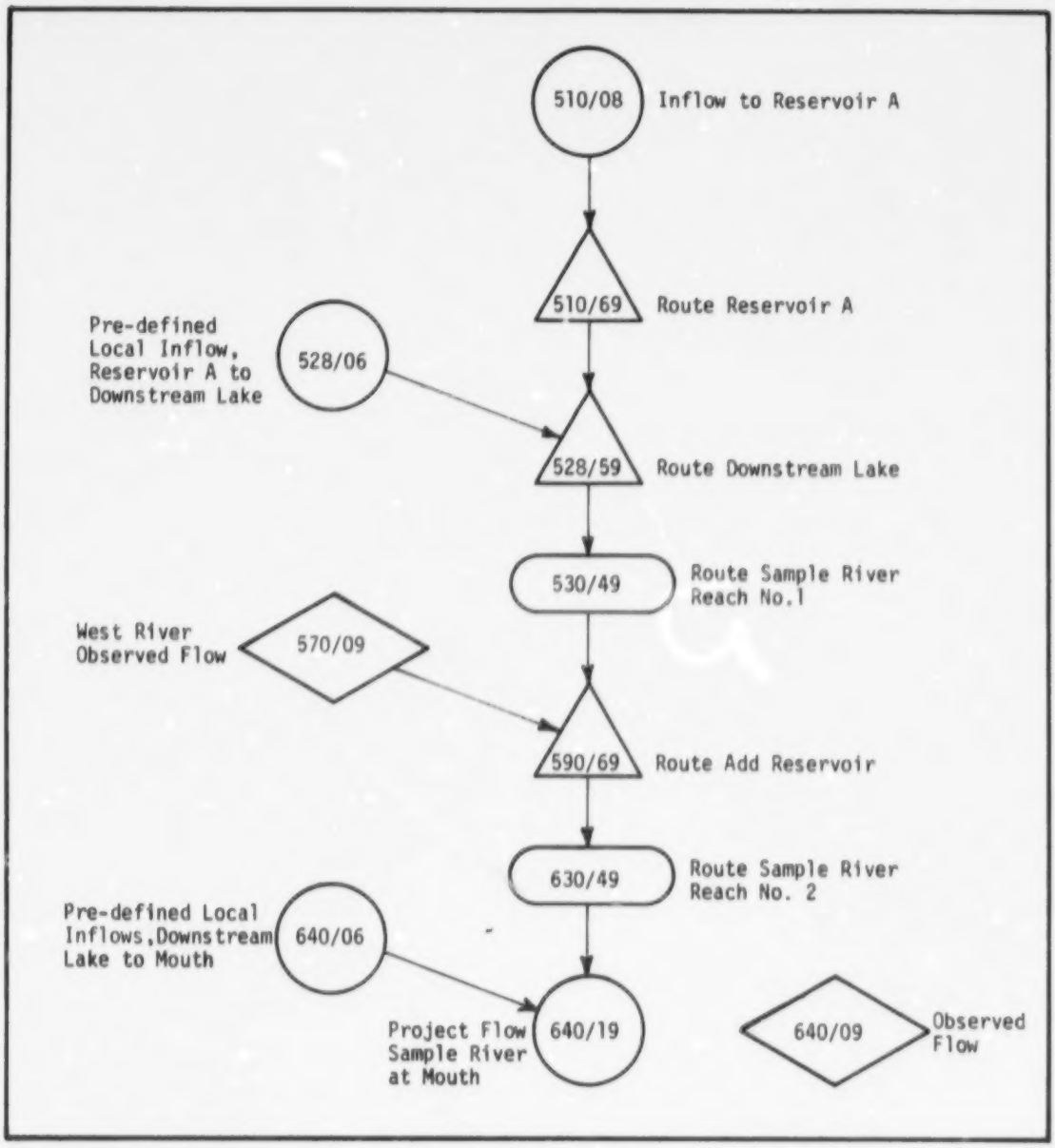


FIGURE 3.22: Flow Chart of Sample Model Inserting a Project Within a Reach

```
SAMPLE MODEL. INSERTING A PROJECT WITHIN A REACH
       51008            1      INFLOW TO RESERVOIR A
       51069            9 1    RESERVOIR ROUTE, RESERVOIR A
       52806            1      PRE-DEFINED LOCAL INFLOW, RES A TO DWST LAKE
       52859            9 1    LAKE ROUTE, DOWNSTREAM LAKE
       53049            1      ROUTE SAMPLE RIVER, REACH NO. 1
       57009            1      WEST RIVER OBSERVED FLOW
       59069            9 1    RESERVOIR ROUTE, ADDED RESERVOIR
       63049            1      ROUTE SAMPLE RIVER, REACH NO. 2
       64006            1      PRE-DEFINED LOCAL INFLOW, DWST LAKE TO MOUTH
       64019            1      PROJECT FLOWS, SAMPLE RIVER AT MOUTH
       64009            1      OBSERVED FLOWS, SAMPLE RIVER AT MOUTH
$END
1  5 1980  31  7 1980      0    2    1    0    0    0    1    2    1
RESEV      51069     51008          -999999999 1 9 9  315770.
LAKE       52859     51069     52806                     56.63
REACH      53049     52859                          1       0.2       25.0
RESEV      59069     53049     57009-999999999 1 9 9  185000.
REACH      63049     59069                          2       0.2       22.0
ADD        64019     63049     64006                1
PLOT                                                 2
           64019     1    C         0       5000
           64009     1    N         0       5000
$END
$END
```

FIGURE 3.23: SIMPAK Input Control Data for Sample Model Inserting a Project Within a Reach

for one phase $TS = \frac{KTS}{Q^n}$

$$= \frac{19.0}{Q^{0.2}}$$

Choosing a representative value of Q as 3,000 cms gives

$$TS = 3.8 \text{ hrs.},$$

therefore total time of storage = 7.6 hrs. at 3,000 cms.

The new reach should have about two-thirds the travel time of the original, and since time of storage is approximately equal to the travel time, the new total time of storage can be estimated as 2/3 x 7.6 hrs = 5.1 hrs. Also, each phase of routing represents a short section of river channel, and in this example one-half of the reach would be represented by one phase of routing. The best representation of the revised reach

is therefore one phase of routing having a total time of storage of 5.1 hrs. The n value does not change with changes in length of the channel.

The KTS value for the revised reach can now be computed using Q = 3,000 cms;

$$TS = \frac{KTS}{Q^n}$$

$$KTS = TS\ Q^n$$
$$= 5.1 \times (3{,}000)^{0.2}$$
$$= 25$$

The new reach is now fully defined and can be represented in the model control instructions using the parameters

n = 0.2
NPS = 1
KTS = 25

The model control data for the revised model is shown in Figure 3.22.

There may be many other modifications required to simulate various projects on a river. The above examples in Sections 3.3.1, 3.3.2, and 3.3.3 give the most common types of modifications and provide the basic processes for altering models.

3.4 Interfacing Segments of a Model

The Yukon River model consists of three separate segments, each comprising a major sub-basin of the river. These segments may be included or deleted as desired for any given use of the model, however at each intersecting point between the segments, the data for the intersecting nodes must be transferred from the upstream to the downstream segment.

This transfer of data is normally brought about by temporarily storing data in a computer file when running the upstream segment and reading this data from the file when running the downstream segment.

Data is stored in files by either the FILE operation or the WLNR operation. The FILE operation writes the data to a file in SSARR card format while the WLNR operation writes the data in internal machine code. Of the two, WLNR is more efficient but has the drawback that data cannot be directly printed or punched on computer cards. In the following example a FILE operation could be used in place of WLNR.

To illustrate this data transfer process an example from the Yukon model is used. Figure 3.24 shows a schematic diagram for the points of intersection of three segments of the model. As can be seen in the diagram, station 72008 "Teslin River at Mouth" is common to both the Teslin River segment and the segment for Yukon River above Carmacks. Station 16508 "Yukon River at Carmacks" is common to both upstream and downstream portions of the Yukon River.

In a run of the model where projects are being tested on the Teslin River to determine effects on the downstream portion of the Yukon River, data for both station 72008, "Teslin River at Mouth, Project Flows", and station 16508, "Yukon River at Carmacks, Project Flows", must be pre-computed using the relevant segments of the model and must be available on files to be read by the downstream segment.

In order to store data for station 72008, the Teslin River segment would have a configuration ending as follows:

```
ADD     72008     79049     9572006
WLNR    72008
```

This would store data for station 72008 to a long record file for later use. In this case the file would be a sequential file specified by the run specifications for logical unit 15 on the computer.

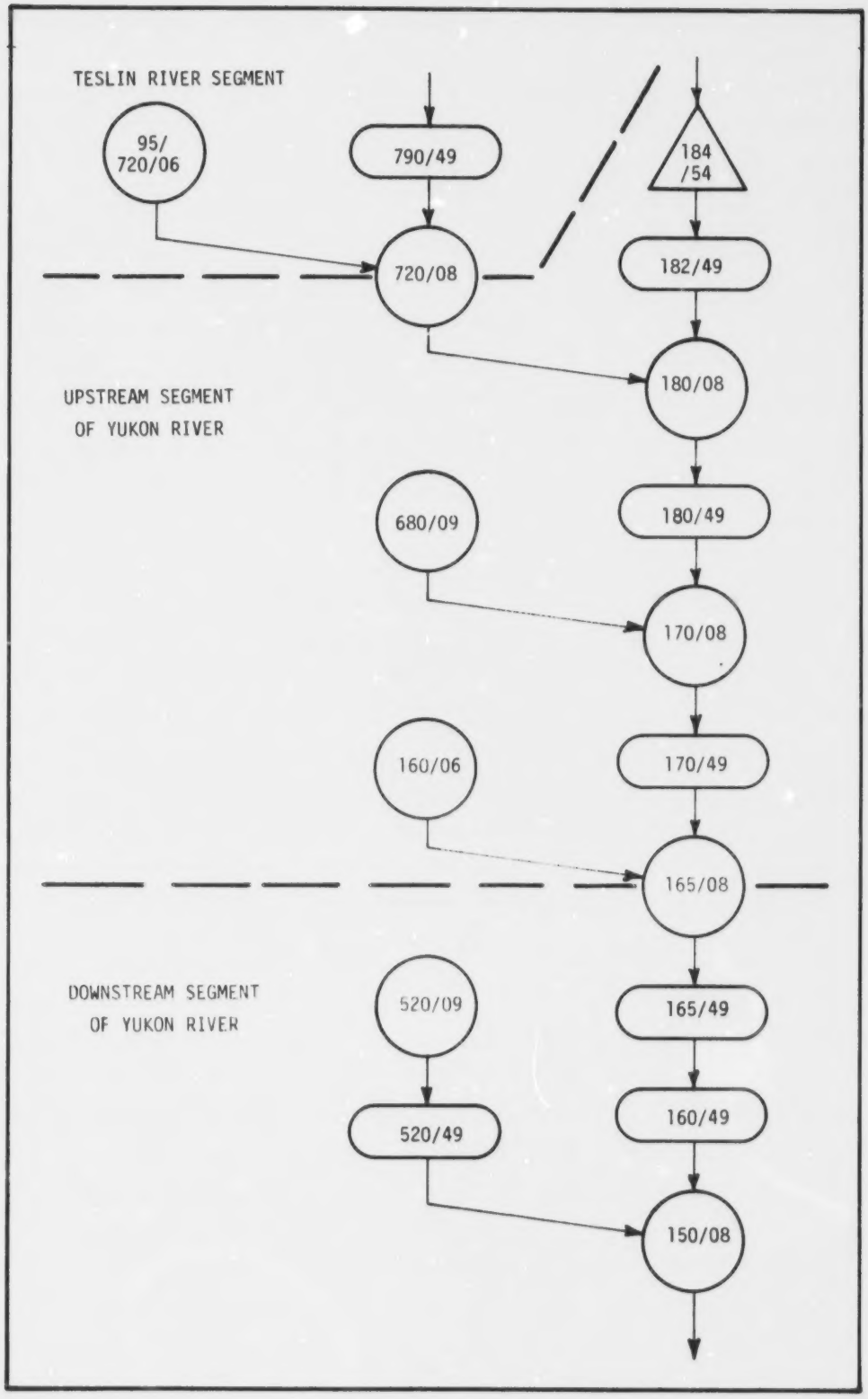


FIGURE 3.24: Flow Chart of Interfacing Segments of a Model

The stored data for station 72008 must be input to upstream segment of Yukon River and the model would have a configuration ending as follows:

ADD	72008	9572006	79049
REAC	18249	18454	
ADD	18008	18249	72008
REAC	18049	18008	
ADD	17008	18049	68009
REAC	17049	17008	
ADD	16508	17049	16006
WLNR	16508		

This would store data for station 16508 to a long record file. This file would probably be the same file as used to store station 72008 above and it would be specified by the run specifications as entering the computer through logical unit 15. Note that if desired, a SSARR formatted file could be used instead of a long record file. In this case the WLNR instruction would be replaced with a FILE instruction, the output file would be defined on logical unit 7 and the input file to next segment would be defined on logical unit 16.

The downstream segment of the Yukon River would have a configuration as follows:

REAC	16549	16508	
REAC	16049	16549	
REAC	52049	52009	
ADD	15008	16049	52049

The station list for the segment would include station 16508 and the run specifications would define logical unit 12 for long record file (or logical unit 16 for SSARR formatted data) as the file holding this data.

In a run where no projects upstream of the segment are being tested, the project flows feeding into the model, i.e. stations 72008 and 16508 would be replaced with recorded flows held under another

station number. In this case the corresponding recorded flows would be held in stations 72009 and 16509. To bring about this change, all references to stations 72008 and 16508 in the model operation cards would be changed to stations 72009 and 16509 respectively, and the recorded flows held under these station numbers would be read from the relevant files. The recorded stations would also have to be included in the station list within the model control instructions.

3.5 Interfacing Time Segments

There is a limit to the time period that can be simulated on any one run of the model. This depends upon the size of the computer and the dimensions of the SIMPAK program version being used. Formerly, only one year could be run at a time. Latest versions of the program, however, allow longer periods to be run. If the period of time to be simulated exceeds the time capacity of the program, it will be necessary to break the job into two or more time segments.

At the beginning of each run, the initial conditions must be set up for each lake and reservoir, and may if desired be specified as well for other routing operations. These initial conditions are specified on the operation instructions within the model control data; the fields to specify are defined in the SIMPAK User's Manual. The initial conditions will be obtained either from the observed conditions on the lakes or reservoirs or from the final day of simulation of the run for the previous time segment.

Many of the operations within the model will produce default initial conditions if they are not specified. For example if no initial condition is specified for a lake, the default condition will consider the lake to be in equilibrium with starting outflow equal to the starting inflow. Likewise reservoirs may default to the input control elevation or control storage values (the default won't work for reservoirs if the control valves are discharges or change-in-storage).

Whenever possible, time segments for the model should begin at periods of steady flow on the river when lakes and reaches are in a state of equilibrium. In such cases the initial conditions do not need to be specified and very little error will result from the default conditions. In this way running several time segments is greatly simplified.

CHAPTER 4
TESLIN RIVER

This chapter describes the Teslin River routing model. A basin map, flow charts for the project and local inflow models, and a routing parameter summary are provided. The model control instructions and required tables, etc. as well as sample outputs from the model are also included.

4.1 Teslin River SIMPAK Model

The Teslin River portion of the Yukon Basin Model begins at Teslin Lake and carries through to the Yukon River confluence. A map of the Teslin River basin is shown in Figure 4.1. As shown on the map, the river flows in a fairly direct line in a northwesterly direction from the lake to its mouth. The river is well confined between steep banks for about 55 kilometres downstream of Teslin Lake, then the valley bottom widens and the river course becomes more convoluted.

The WSC hydrometric stations that are used in this model are shown in SIMPAK notation on the map in Figure 4.1. Table 4.1 lists all the WSC hydrometric stations used in the model and lists both WSC notation and SIMPAK model notation. It should be noted that the station "Teslin River near Teslin" has complete records for the study period (1960-81) while the station "Teslin Lake at Teslin" has many missing data periods. A relationship between the stages of these two stations was developed and lake levels for "Teslin Lake at Teslin" were generated for the whole study period based on this relationship. Inflows to Teslin Lake were then computed using the generated lake levels and recorded outflows at "Teslin River near Teslin". Figure 4.2 shows the SIMPAK model flow chart for computing inflows to Teslin Lake.

The ungauged flows from the outlet of Teslin Lake to the Yukon River confluence were computed as local inflows. As shown in Figure 4.3

lake outflows at the station "Teslin River near Teslin" were routed down to the Yukon River confluence using the routing parameters shown in Table 4.2. Local inflows were then computed as the station "Teslin River near Whitehorse" minus the routed flows. It should be noted that the routing parameters were calibrated using recorded flows at "Teslin River near Teslin" and "Teslin River near Whitehorse". Figure 4.4 shows the control instructions for the local inflow model. The WLNR operation in this model stores local inflows in long record format for later use by a project model.

Figure 4.5 gives a flow chart for the project model of the Teslin River. Figure 4.6 shows the model control instructions giving the configuration for a project model which simulates a release pattern for a hypothetical reservoir located at Teslin Lake. Table 4.3 gives the storage table for Teslin Lake. In this example inflows were routed through Teslin Lake with outflows controlled to provide a firm release of 237 cubic metres per second throughout the freshet. The WLNR operation in this model stores the regulated outflows for Teslin River at the mouth for further use as input to the next segment. Figure 4.7 shows computer plots from reservoir regulation of the Teslin River project model. A comparison of the natural outflows and the regulated outflows from a hypothetical reservoir at Teslin Lake is shown in the plots. The symbol "S" in the plots represents the reservoir storage curve while symbols "O" and "R" represent natural and regulated outflows respectively. Where the two outflow hydrographs overlap, only the "R" is shown. The recorded natural flows and regulated flows for Teslin River at the mouth are given in the upper portion of the plots which shows the regulation effect by the hypothetical reservoir upstream at Teslin Lake.

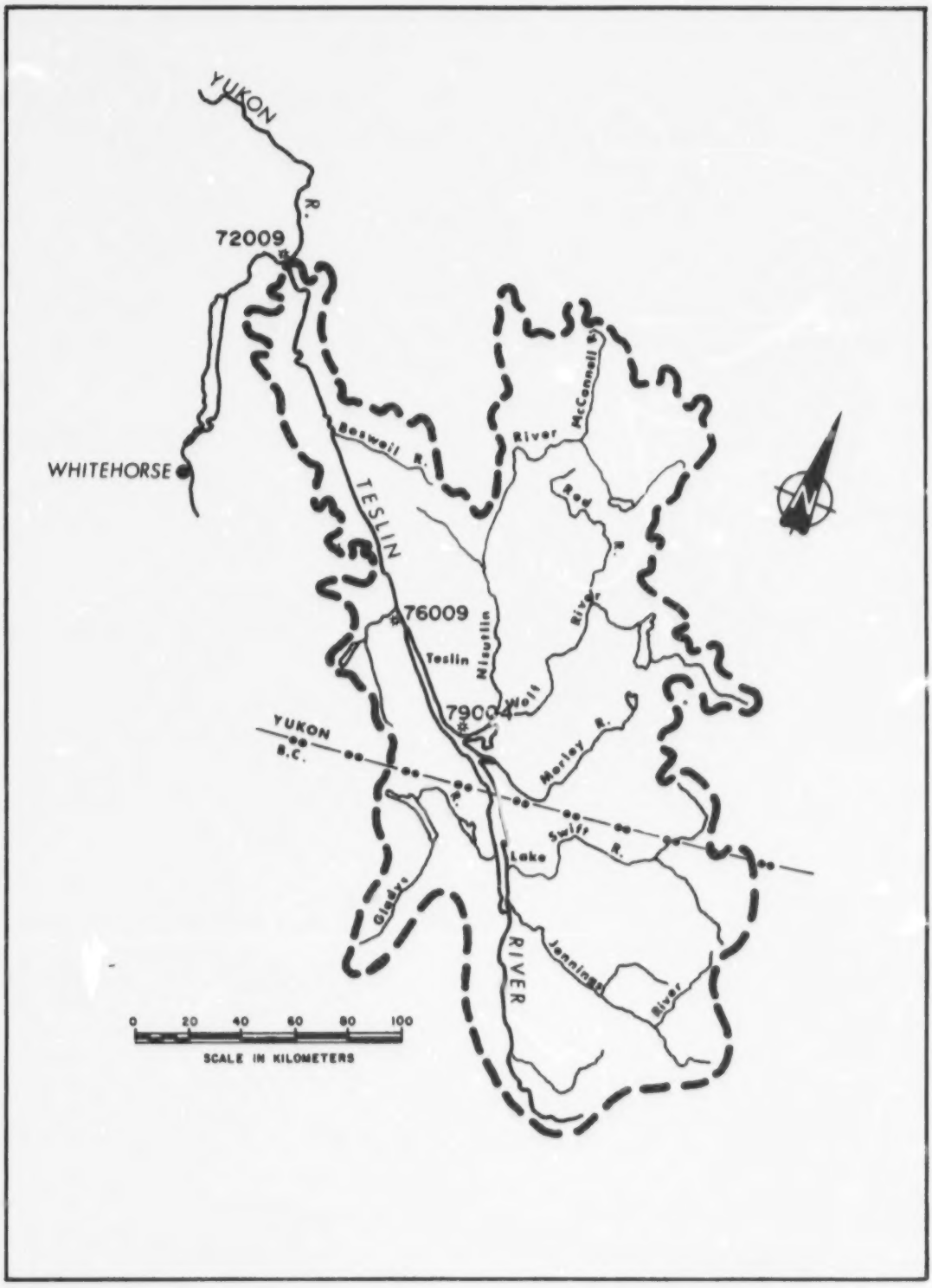


FIGURE 4.1: Map of Teslin River Portion

Table 4.1: Gauging Stations Required for Routing Teslin River Flows

Gauging Station	WSC Number	SIMPAK Number
Teslin River near Teslin	09AE001	76009
Teslin River near Whitehorse	09AF001	72009
Teslin Lake at Teslin	09AE002	79004

Note: A "90" is prefixed to the SIMPAK number if the station data has been adjusted or extended.

Table 4.2: SIMPAK Model Routing Parameters for Teslin River

Teslin River Reaches	SIMPAK Number	Routing Parameters		
		Phases	n	KTS
Outlet of Teslin Lake to Teslin River at Mouth	72049	2	0.2	20

Table 4.3: Storage Table for Teslin Lake

Sequence Number	Stage (metres)	Storage (1000 cubic metres)
1	0	0
2	5.39	1 927 000
3	23.99	9 498 000

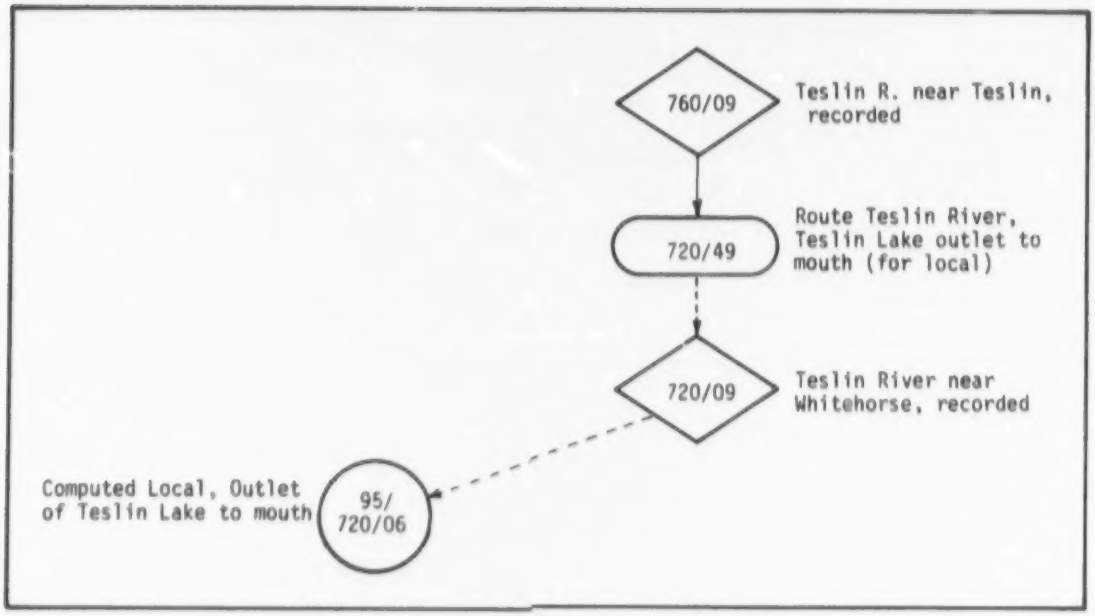

760/09
Teslin R. near Teslin, recorded
720/49
Route Teslin River, Teslin Lake outlet to mouth (for local)
720/09
Teslin River near Whitehorse, recorded
Computed Local, Outlet of Teslin Lake to mouth
95/ 720/06

FIGURE 4.3: SIMPAK Local Model Flow Chart for Routing Teslin River Flows

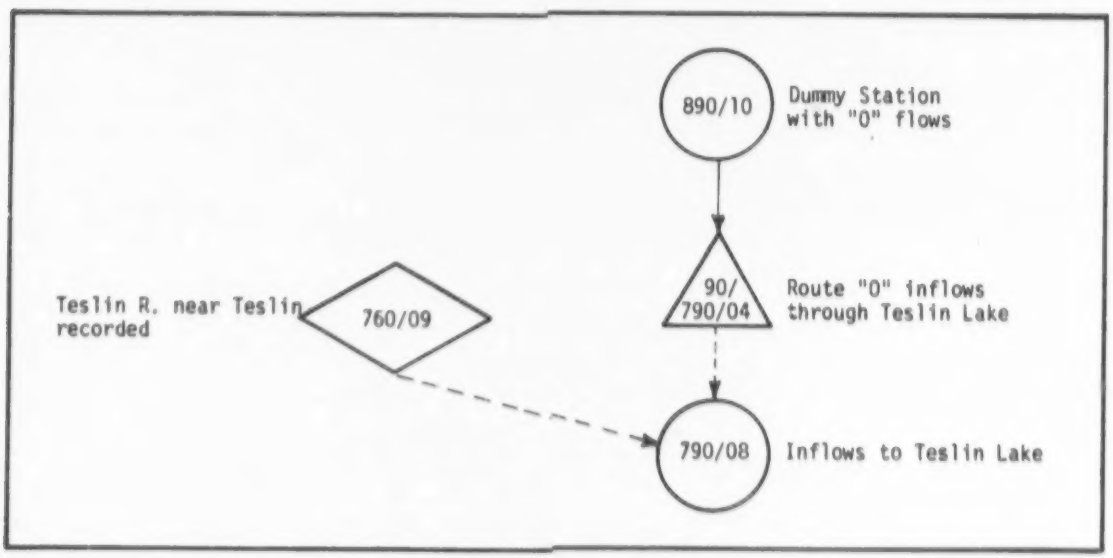


FIGURE 4.2: SIMPAK Model Flow Chart for Computing Inflows to Teslin River

```
YUKON-: IMPAK MODEL (SUB-MODEL NO. 938)-COMPUTATION OF LOCAL INFLOWS, TESLIN RIVER
        76009          1       TESLIN R. NEAR TESLIN (09AE001), RECORDED
        72049          1       ROUTE TESLIN R., TESLIN LAKE OUTLET TO TESLIN R. MOUTH
        72009          1       TESLIN R. NEAR WHITEHORSE (09AF001), RECORDED
      9572006          1       LOCAL INFLOWS, TESLIN LAKE OUTLET TO TESLIN R. MOUTH
$END
01 01 1964  31 12 1964                                  1    1    2
REAC      72049     76009                        2          0 2       20 0
SUBT    9572006     72009     72049              1 1 1
WLNR    9572006                                  1
$END
$END
```

FIGURE 4.4: SIMPAK Local Model Instructions for Routing Teslin River Flows

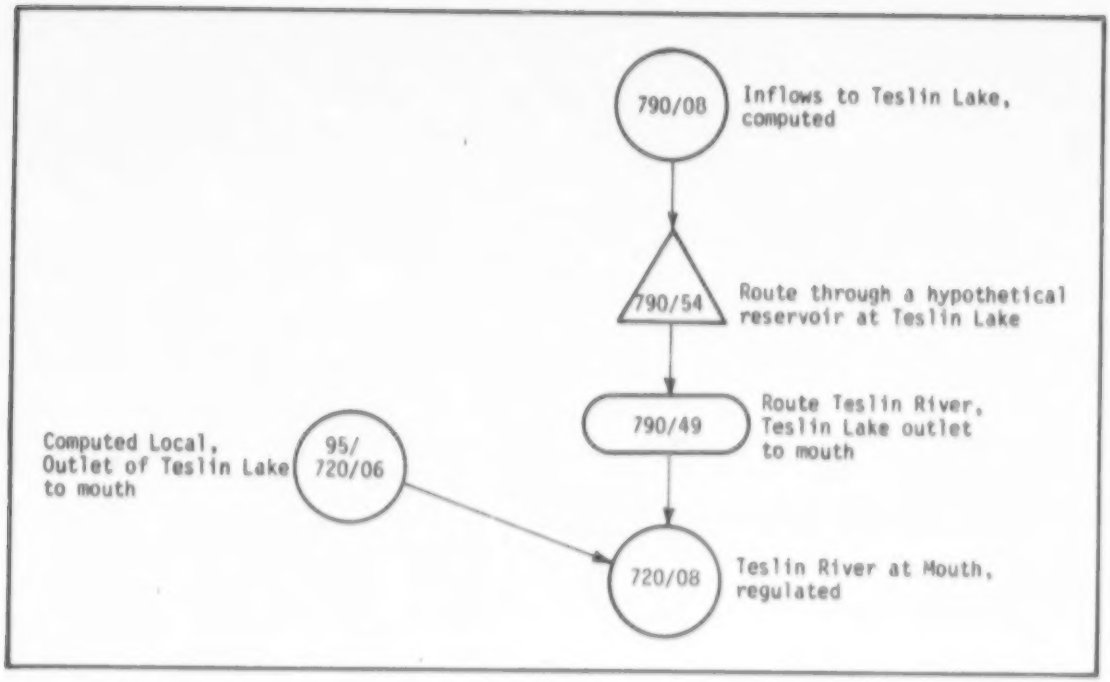

790/08
Inflows to Teslin Lake, computed
790/54
Route through a hypothetical reservoir at Teslin Lake
790/49
Route Teslin River, Teslin Lake outlet to mouth
Computed Local, Outlet of Teslin Lake to mouth
95/ 720/06
720/08
Teslin River at Mouth, regulated

FIGURE 4.5: SIMPAK Project Model Flow Chart for Teslin River Portion

```
YUKON SIMPAK MODEL (SUB-MODEL MOD 4131-PROJECT MODEL FOR TESLIN RIVER BRANCH
        79008          1      INFLOWS TO TESLIN LAKE, COMPUTED
        79054          0 1    ROUTE THROUGH TESLIN LAKE RESERVOIR
        76009          1      TESLIN R  NEAR TESLIN, RECORED
        79049          1      ROUTE TESLIN R , TESLIN LAKE OUTLET TO TESLIN R  AT MOUTH
      9572006          1      LOCAL INFLOWS, TESLIN L  OUTLET TO TESLIN R  AT MOUTH
        72008          1      TESLIN R  AT MOUTH, COMPUTED
        72009          1      TESLIN R  AT MOUTH, RECORDED
$END
01 05 1964  31 07 1964              1    1                  1    1    2
RESE       79054      79008                                1 0 0 1155000      0.471      2.701
REAC       79049      79054                               2           0.2    20.0
ADD        72008      79049    9572006                    1 1 1
PLOT                                                      3
           76009    1    0          0      2000
           79054    2    5          0        10
           79051    1    R          0      2000
PLOT                                                      2
           72009    1    0          0      2000
           72008    1    R          0      2000
@LNR       72008                                          1
$END
$END
```

FIGURE 4.6: SIMPAK Project Model Instructions for Teslin River Portion

T 76009 TESLIN R NEAR TESLIN REQUIRED CMS
VARIABLE 1 0 200 400 600 800 1000 1200 1400 1600 1800 2000
S 79054 ROUTE THROUGH TESLIN LAKE RESERVOIR METER
VARIABLE 2 0 1 2 3 4 5 6 7 8 9 10
O 79054 ROUTE THROUGH TESLIN LAKE RESERVOIR CMS
VARIABLE 1 0 200 400 600 800 1000 1200 1400 1600 1800 2000

FIGURE 4.7: SIMPAK Plots for Reservoir Regulation at Teslin Lake

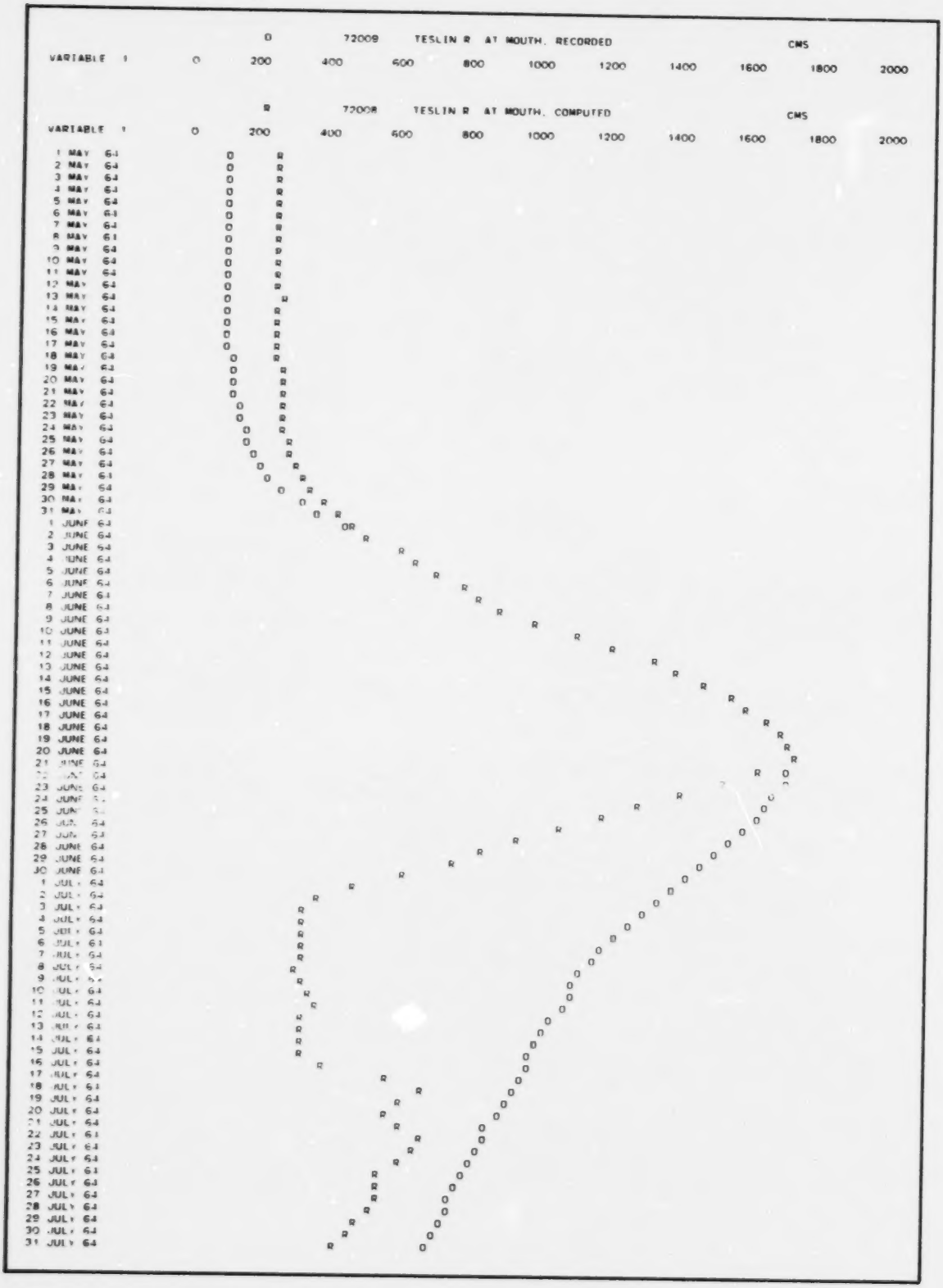


FIGURE 4.8: SIMPAK Plots for Regulation Effect at Teslin River near the Mouth

CHAPTER 5
UPSTREAM PORTION OF YUKON RIVER

This chapter describes the routing model for the upstream portion of the Yukon River including the headwater lakes. A basin map, flow charts for the project and local inflow models and a routing parameter summary are provided. The model control instructions and required tables, etc. as well as sample outputs from the model are also included.

5.1 SIMPAK Model for Upstream Portion of Yukon River

The Yukon River rises in northern British Columbia and flows in a generally northwesterly direction across the Yukon to a point 144 kilometres northwest of Dawson City where it crosses the border and flows into Alaska. A series of headwater lakes, namely Atlin, Bennett, Tagish and Marsh Lakes as well as Lake Laberge, provide natural regulation on the Yukon River flows. The upstream portion of the Yukon River referred to in this report is that portion of the river from the headwater lakes to Carmacks excluding the Teslin River which joins the Yukon River about half way between Whitehorse and Carmacks.

A map of the upstream portion of the Yukon River is provided in Figure 5.1, showing the WSC hydrometric stations that are used in this model in their SIMPAK notation. Table 5.1 lists all the WSC hydrometric stations used in the model and lists both WSC notation and SIMPAK notation. It should be noted that the station "Atlin River near Atlin" has complete records for the study period (1960-81) while the station "Atlin Lake at Atlin" has many missing data periods. The rating table used for lake outflows at "Atlin River near Atlin" was directly related to Atlin Lake levels. Using the rating table and the record of lake outflows, lake levels for "Atlin Lake at Atlin" were generated for the whole study period. Inflows to Atlin Lake were then computed using the lake outflows at "Atlin River near Atlin" and the computed Atlin Lake levels. Figure 5.2 shows the SIMPAK model flow chart for computing inflows to Atlin Lake.

At the outlet of Atlin Lake, the Atlin River flows a distance of 4.7 kilometres and drops about 12 metres before entering Tagish Lake. This section of river was considered to have negligible routing effect and so was not included in the model. The rapid fall of the Atlin River was considered to transfer no backwater effect from Tagish to Atlin Lakes.

Tagish, Nares and Bennett Lakes are closely interconnected and, during the summer period, act essentially as one lake. Tagish and Marsh Lakes are connected by a short channel 7.4 kilometres in length with a drop of only approximately 0.2 metres during high water and 0.3 metres during low water periods. Tagish and Nares Lakes are joined by a narrows that does not restrict flows. Nares and Bennett Lakes are joined by a short channel that varies in length and drop depending upon the level of Nares Lake. The backwater effects in these channels are such that the levels of Tagish, Nares and Bennett Lakes are all controlled by Marsh Lake.

Field surveys reported in Appendices A and B of this report provide data for use in determining the complex backwater relationships among Marsh, Tagish, Nares and Bennett Lakes. These surveys concluded that Tagish and Nares Lakes act as a single lake at all times, while Marsh, Tagish and Bennett Lakes act as separate lakes, each controlled through a backwater relationship from the downstream lake. Time and data available for this study did not permit the modelling of these lakes as separate backwater lakes, although with additional studies that type of modelling could be accomplished within the Yukon Basin Model.

Previous studies of regulation of Marsh-Tagish-Nares-Bennett Lakes have considered all four lakes to rise and fall together and thereby act as a single lake. That assumption is a simplification of the actual backwater condition, but should provide acceptable estimates of lake levels, storages and discharges. For the purposes of the

Yukon Basin Model, since it was not possible within the study constraints to develop the required data to operate as separate lakes, the four lakes Tagish, Nares, Bennett and Marsh were combined, and were modelled as a single lake termed "Bennett-Tagish-Marsh Lakes".

The first section of Figure 5.3 shows the SIMPAK model flow chart for computing local inflows to Bennett-Tagish-Marsh Lakes. Firstly, local inflows from the Marsh Lake Control Dam down to Yukon River at Whitehorse were estimated in the model by applying a drainage area ratio to station "McClintock River near Whitehorse". Marsh Lake outflows were then computed by subtracting the local inflows from the recorded flows for "Yukon River at Whitehorse". Using these computed Marsh Lake outflows and the recorded Marsh Lake levels, the total inflows to Bennett-Tagish-Marsh Lakes were computed. The local inflows to the lakes were then computed by subtracting Atlin River flows.

Recording of Lake Laberge levels began in July 1980. To compute levels back to 1960, a curve showing the relationship between stages at Lake Laberge and the station "Yukon River above Frank Creek" was used. The latter station has long term records covering the whole study period. The relating curve was plotted based only on data for 1981-83 when recorded stages at Lake Laberge are available. This curve, which shows a good correlation between the two stations, was used to estimate Lake Laberge levels for periods between 1960 and 1981. Inflows to Lake Laberge were then computed by a backrouting procedure using the estimated lake levels and considering the discharges at Frank Creek as outflows from the lake. Subsequently the local inflows to the lake were computed as shown in the second section of Figure 5.3. The local inflows exclude the gauged inflows from the Takhini River.

The third section of Figure 5.3 shows the SIMPAK model flow chart for computing local inflows between Frank Creek and Carmacks, excluding

the gauged inflows from Teslin River and Big Salmon River. Flows at "Yukon River above Frank Creek" were routed down to Carmacks using the routing parameters listed in Table 5.2. The parameters were calibrated using the trial method described in Chapter 3. These routed flows were then subtracted from the recorded flows at Carmacks to obtain local inflows. Figure 5.4 shows the control instructions for the local inflow model for this portion of the Yukon River. The WLNR operation in the model stores the local inflows in long record format for later use by a project model.

Figure 5.5 gives a project model flow chart for routing the upstream portion of the Yukon River. Figure 5.6 shows the model control instructions for a project model which simulates a hypothetical control pattern for Bennett-Tagish-Marsh Lakes. Tables 5.3 to 5.5 give the storage tables for the lakes in this project model. It should be noted that two TRSF operations shown in Figure 5.6 for stations 89054 and 84054 are not shown in Figure 5.5. The operations were inserted to set reservoir control patterns for the sample run shown in Figures 5.7 and 5.8. These operations can be removed if the control patterns have been stored in a data file prior to the project run. The SUBT operation for station 9019008 was inserted to compute Marsh Lake observed outflows for plotting only and is not a necessity for the project run. In this example outflows were controlled to provide a firm flow release of 182 cubic metres per second prior to freshet. It should be noted that a project or project combination can also be inserted at Atlin Lake or Lake Laberge to provide additional regulation on Yukon River flows. The WLNR operation in this model stores the regulated flows at Carmacks for later use as input to the next segment. Figure 5.7 shows computer plots from a sample run of the project model for the upstream portion of the Yukon River. A comparison of the natural outflows and regulated outflows from the hypothetical operation of Bennett-Tagish-Marsh Lakes is shown in the plots. The recorded natural flows and regulated flows at the outlet of Lake Laberge for the same sample run are shown in Figure 5.8.

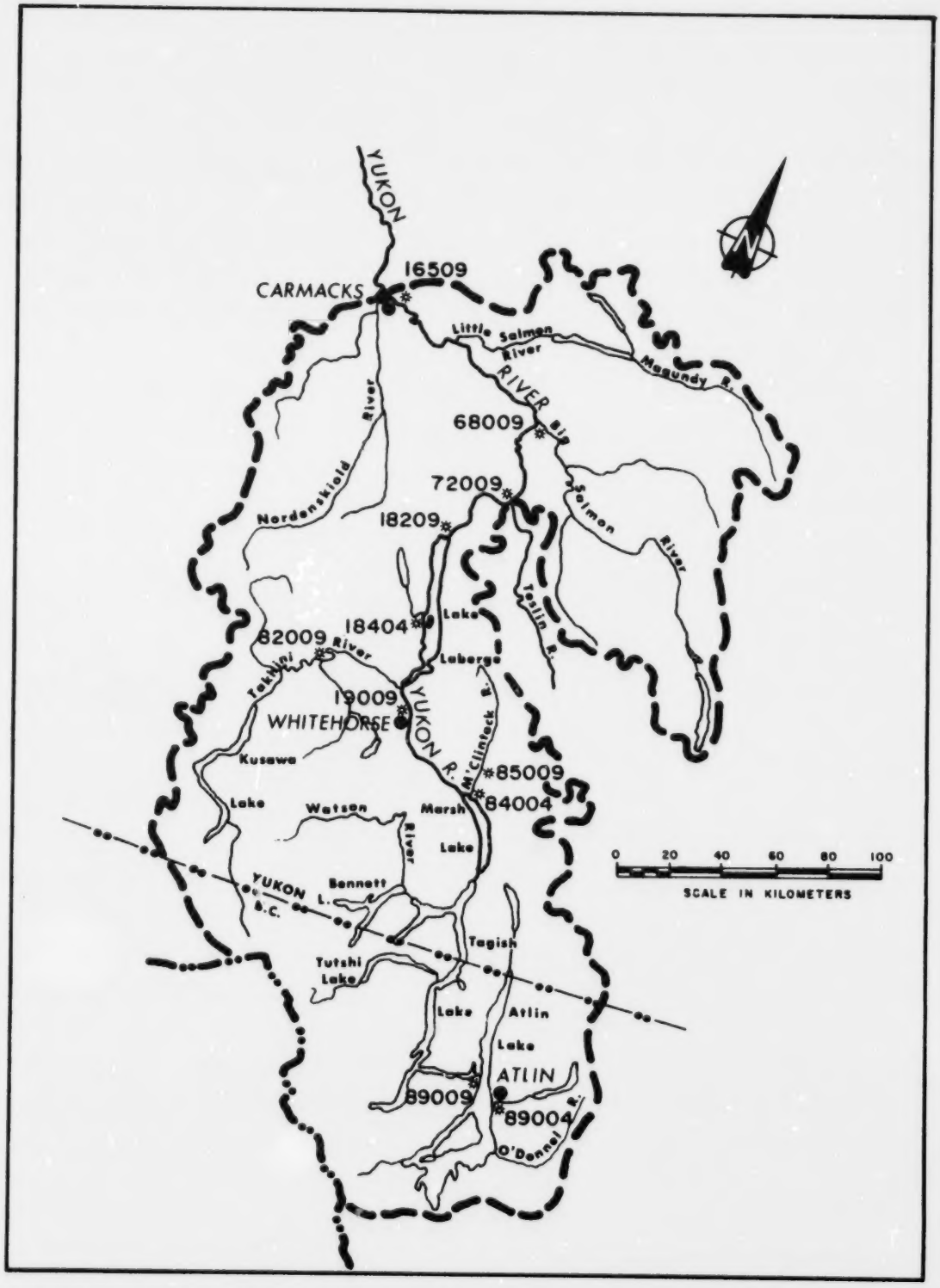


FIGURE 5.1: Map of Upstream Portion of Yukon River Basin

Table 5.1: Gauging Stations Required for Routing Upstream Portion of Yukon River

Gauging Station	WSC Number	SIMPAK Number
Teslin River near Whitehorse	09AF001	72009
Atlin River near Atlin	09AA006	89009
Atlin Lake at Atlin	09AA001	89004
M'Clintock River near Whitehorse	09AB008	85009
Marsh Lake near Whitehorse	09AB004	84004
Yukon River at Whitehorse	09AB001	19009
Takhini River near Whitehorse	09AC001	82009
Lake Laberge near Whitehorse	09AB010	18404
Yukon River above Frank Creek	09AB009	18209
Yukon River at Carmacks	09AH001	16509
Big Salmon River near Carmacks	09AG001	68009

Note: A "90" or "95" is prefixed to SIMPAK number if the station data extended or computed.

Table 5.2: Simpak Model Routing Parameters for Yukon River Above Carmacks

Yukon River above Carmacks	SIMPAK Number	Routing Parameters		
		Phases	n	KTS
Outlet of Lake Laberge to Yukon R. above Teslin River	18249	2	0.2	30
Yukon R. below Teslin River to Yukon R. ab. Big Salmon R.	18049	2	0.2	30
Yukon R. below Big Salmon R. to Yukon R. at Carmacks	17049	4	0.2	30

Table 5.3: Storage Table for Atlin Lake

Sequence Number	Stage (metres)	Storage (1000 cubic metres)	Discharge (cms)
1	0	0	0
2	0.92	538 000	17.3
3	1.22	718 000	33.1
4	1.52	897 000	58.6
5	1.83	1 077 000	86.9
6	2.13	1 256 000	121.5
7	2.44	1 435 000	162.8
8	2.74	1 615 000	210.1
9	3.05	1 794 000	263.3
10	3.35	1 974 000	320.0
11	3.57	2 099 000	361.9

Table 5.4: Storage Table for Bennett-Tagish-Marsh Lakes

Sequence Number	Stage (metres)	Storage (1000 cubic metres)
1	0	0
2	0.13	586 000
3	3.18	2 050 000
4	5.01	2 940 000
5	8.06	4 749 000
6	11.11	6 669 000
7	14.16	8 717 000
8	15.68	9 785 000

Table 5.5: Storage Table for Lake Laberge

Sequence Number	Stage (metres)	Storage (1000 cubic metres)	Discharge (cms)
1	0	0	0
2	6.04	1 069 000	140
3	6.90	1 234 000	300
4	7.60	1 371 000	460
5	8.80	1 611 000	780
6	15.00	2 940 000	2 340

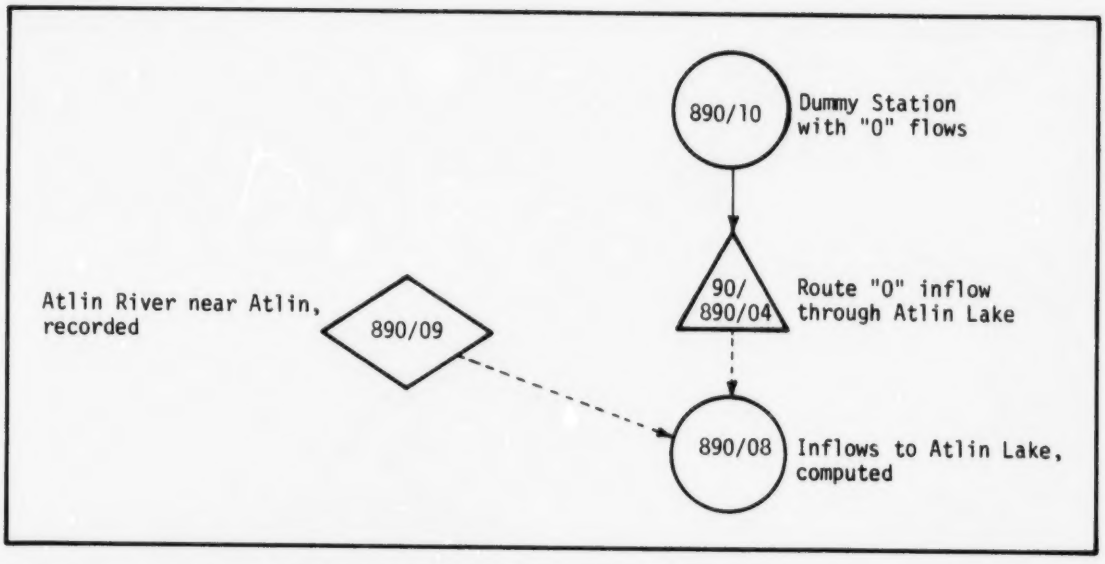


FIGURE 5.2: SIMPAK Model Flow Chart for Computing Inflows to Atlin Lake

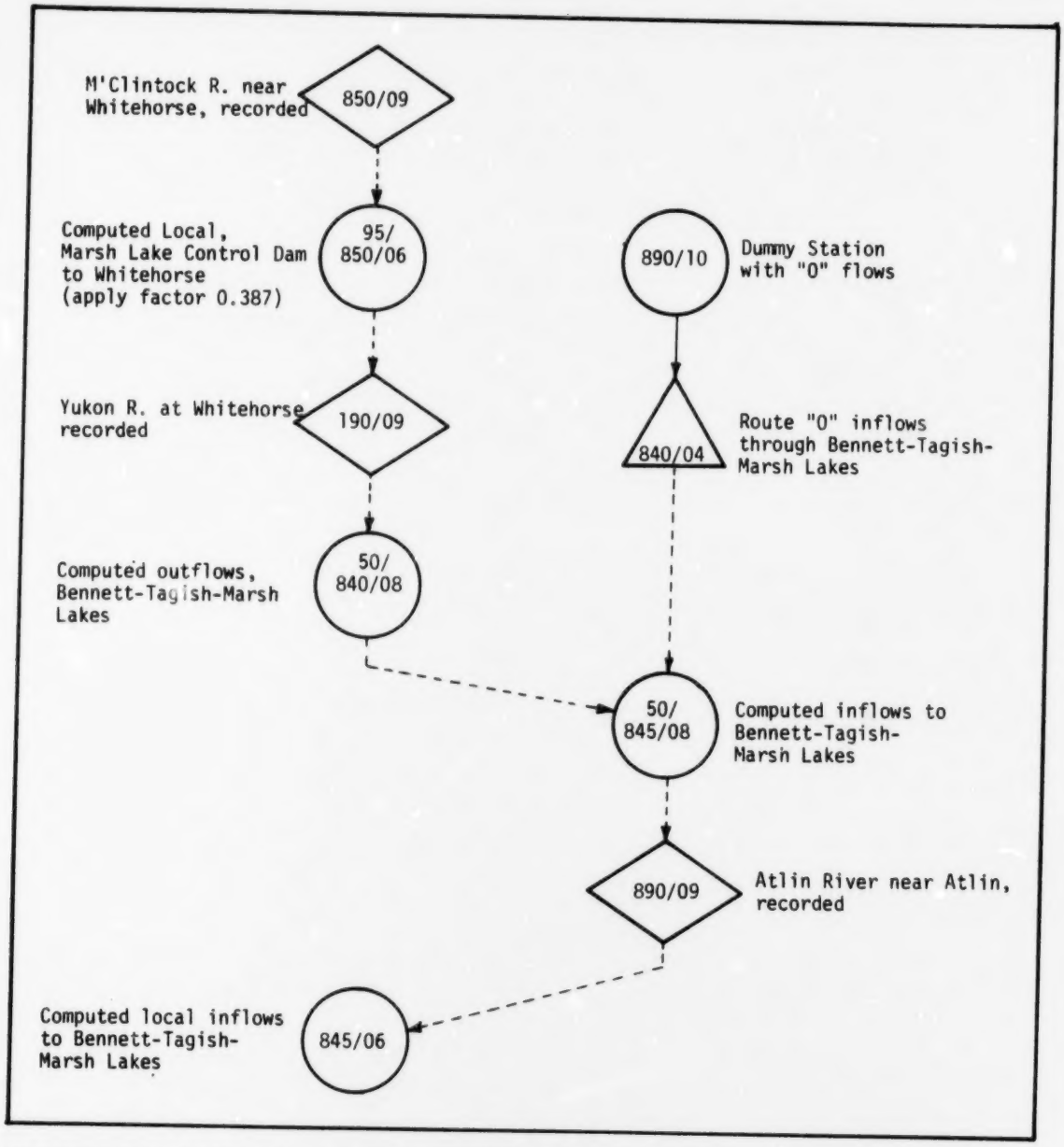


FIGURE 5.3(1): SIMPAK Local Model Flow Chart for Upstream Portion of Yukon River

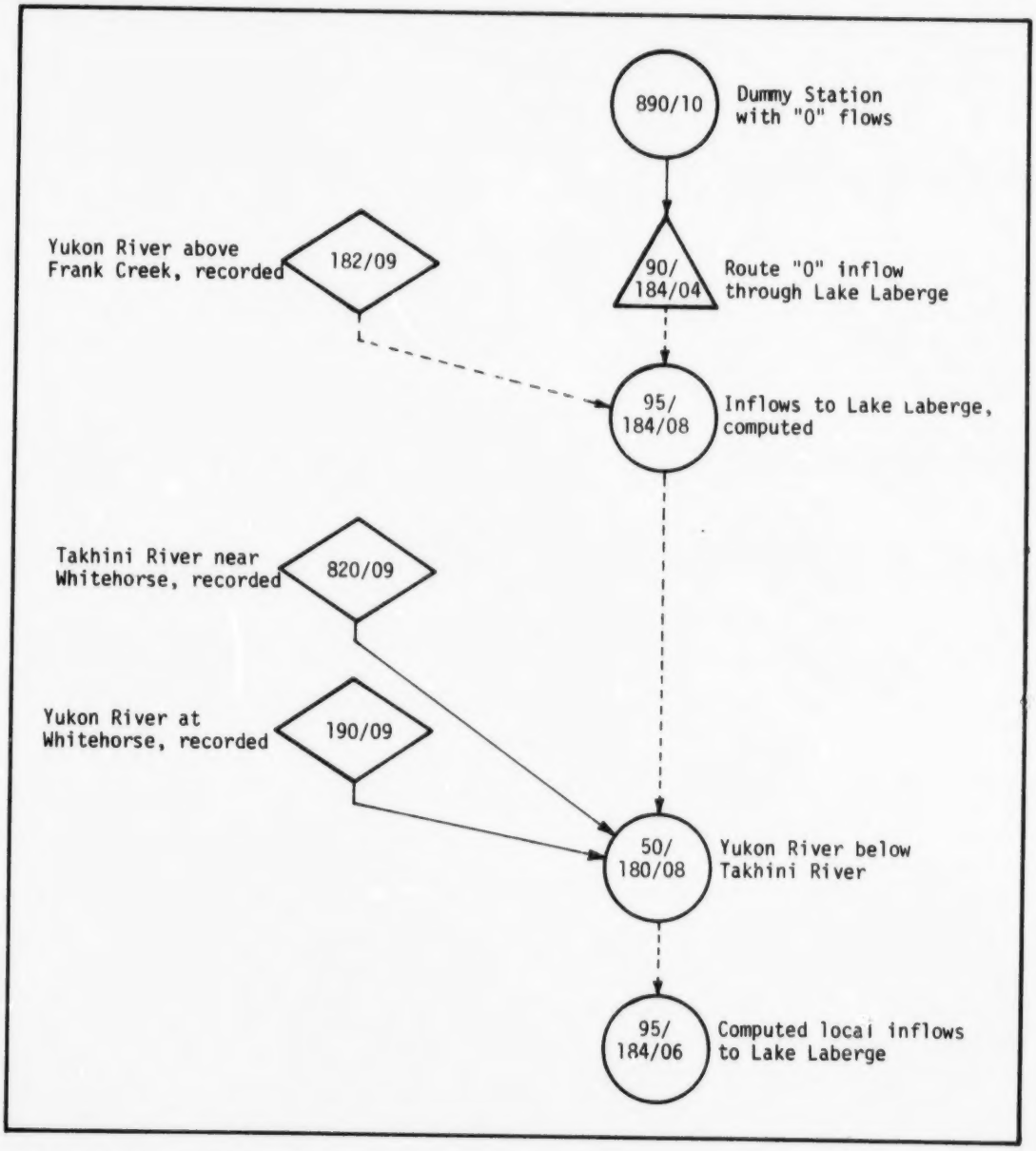


FIGURE 5.3(2): cont'd.

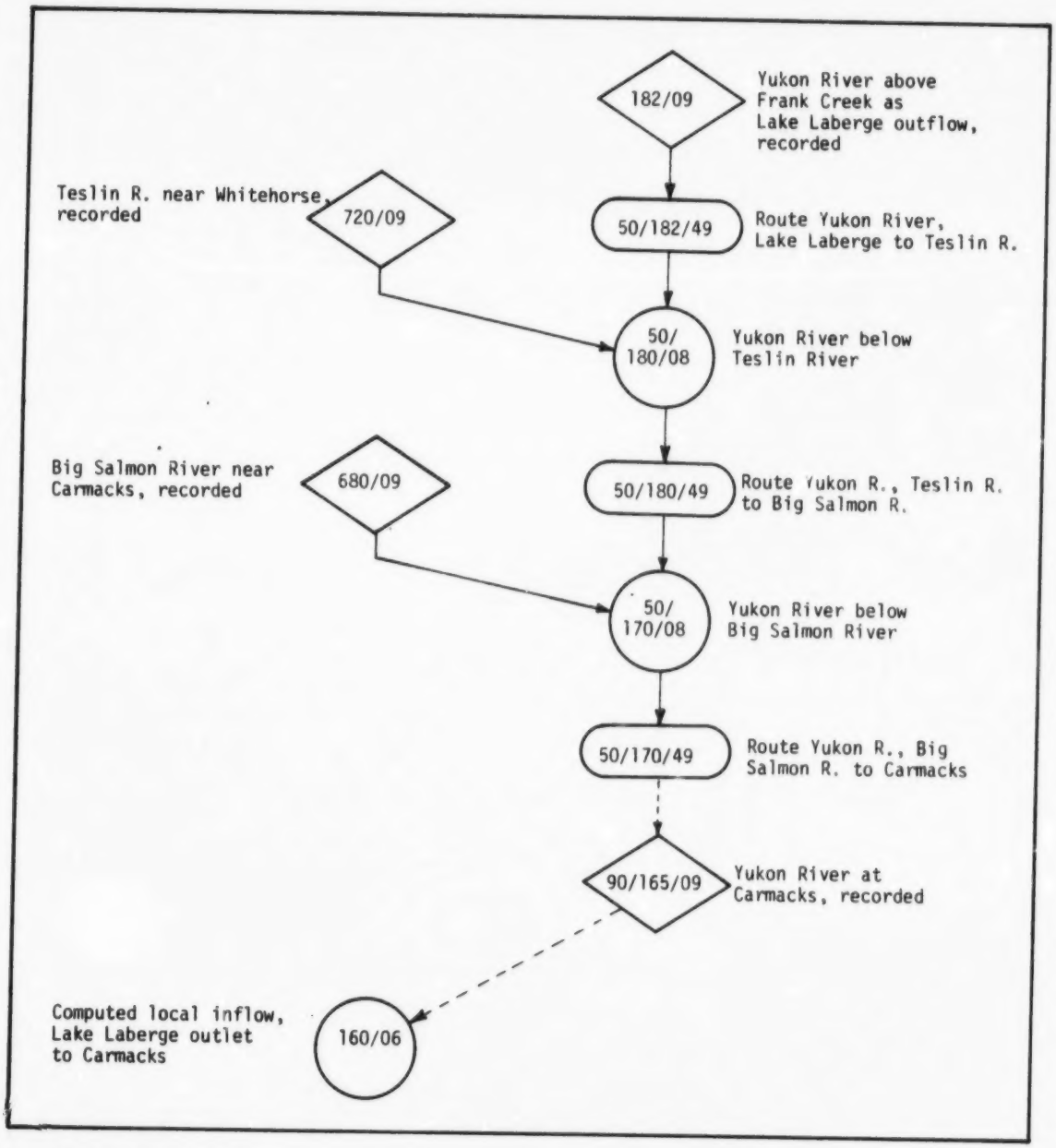

182/09
Yukon River above Frank Creek as Lake Laberge outflow, recorded
Teslin R. near Whitehorse, recorded
720/09
50/182/49
Route Yukon River, Lake Laberge to Teslin R.
50/ 180/08
Yukon River below Teslin River
Big Salmon River near Carmacks, recorded
680/09
50/180/49
Route Yukon R., Teslin R. to Big Salmon R.
50/ 170/08
Yukon River below Big Salmon River
50/170/49
Route Yukon R., Big Salmon R. to Carmacks
90/165/09
Yukon River at Carmacks, recorded
Computed local inflow, Lake Laberge outlet to Carmacks
160/06

FIGURE 5.3(3): cont'd.

```
YUKON SIMPAK MODEL (SUB-MODEL MOD Y1A)-COMPUTATION OF MARSH LAKE INFLOWS
        85009            1       M'CLINTOCK R  NEAR WHITEHORSE
        89010            1       DUMMY STATION WITH ZERO FLOWS
      9585006            1       LOCAL INFLOWS, MARSH LAKE CONTROL DAM TO WHITEHORSE
        19009            1       YUKON R  NEAR WHITEHORSE (09AB001), RECORDED
        89009            1       ATLIN R  NEAR ATLIN, RECORDED
        84004            9 1     ROUTE THROUGH BENNETT-TAGISH-MARSH LAKES
      5084008            1       MARSH LAKE OUTFLOWS, COMPUTED
      5084508            1       COMPUTED INFLOWS TO B-T-M LAKES
        84506            1       LOCAL INFLOWS TO B-T-M LAKES (EXCLDE ATLIN RIVER & LAKE)
$END
01 01 1964  31 12 1964            0    1                1    1    2
TRSF    9585006      85009                          1 1       0 387
SET       89010                                     1           0
RESE      84004      89010              -999999999 2 9 9 1234518
SUBT    5084008      19009   9585006                1 1 1
SUBT    5084508    5084008     84004                1 1 1
SUBT      84506    5084508     89009                1 1 1
WLNR    9585006                                     1
WLNR      84506                                     1
$END
$END


YUKON SIMPAK MODEL (SUB-MODEL MOD Y2) - COMPUTATION OF LOCAL INFLOWS TO LAKE LABERGE
        89010            1       DUMMY STATION WITH ZERO FLOWS
        82009            1       TAKHINI R  NEAR WHITEHORSE (09AC001), RECORDED
        19009            1       YUKON R  NEAR WHITEHORSE (09AB001), RECORDED
      5018406            1       LOCAL INFLOWS TO LAKE LABERGE
      9018404            9 1     ROUTE THROUGH LAKE LABERGE (09AB010), RECORDED
        18209            1       YUKON R  ABOVE FRANK CREEK (09AB009), RECORDED
      5018008            1       YUKON RIVER BELOW TAKHINI RIVER
      9518408            1       INFLOWS TO LAKE LABERGE, COMPUTED
$END
01 01 1964  31 12 1964                 1                1    1    2
ADD     5018008      82009      19009                  1 1 1
SET       89010                                       1           0
RESE    9018404      89010              -999999999 2 9 9           0
SUBT    9518408      18209   9018404                   1 1 1
SUBT    9518406    9518408   5018008                   1 1 1
WLNR    9518406                                       1
$END


YUKON-SIMPAK MODEL (SUBMODEL MOD Y3)-LOCAL INFLOWS, LAKE LABERGE OUTLET TO CARMACKS
        72009            1       TESLIN R  NEAR WHITEHORSE (09AF001), RECORDED
        18209            1       YUKON R  ABOVE FRANK CREEK (09AB009), RECORDED
      5018249            1       ROUTE YUKON R , LAKE LABERGE OUTLET TO TESLIN R
      5018008            1       YUKON R  BELOW TESLIN R
      5018049            1       ROUTE YUKON R , TESLIN R  TO BIG SALMON R
        68009            1       BIG SALMON R  NEAR CARMACKS (09AG001), RECORDED
      5017008            1       YUKON RIVER BELOW BIG SALMON R
      5017049            1       ROUTE YUKON R , BIG SALMON R  TO CARMACKS
      9016509            1       YUKON R  AT CARMACKS (09AH001), RECORDED
        16006            1       LOCAL INFLOWS, LAKE LABERGE OUTLET TO CARMACKS
$END
01 01 1964  31 12 1964                                  1    1    2
REAC    5018249      18209                          2           0 2        30 0
ADD     5018008    5018249      72009                1 1 1
REAC    5018049    5018008                           2           0.2        30.0
ADD     5017008    5018049      68009                1 1 1
REAC    5017049    5017008                           4           0 2        30 0
SUBT      16006    9016509    5017049                1 1 1
WLNR      16006                                     1
$END
$END
```

FIGURE 5.4: SIMPAK Local Model Instructions for Upstream Portion of Yukon River

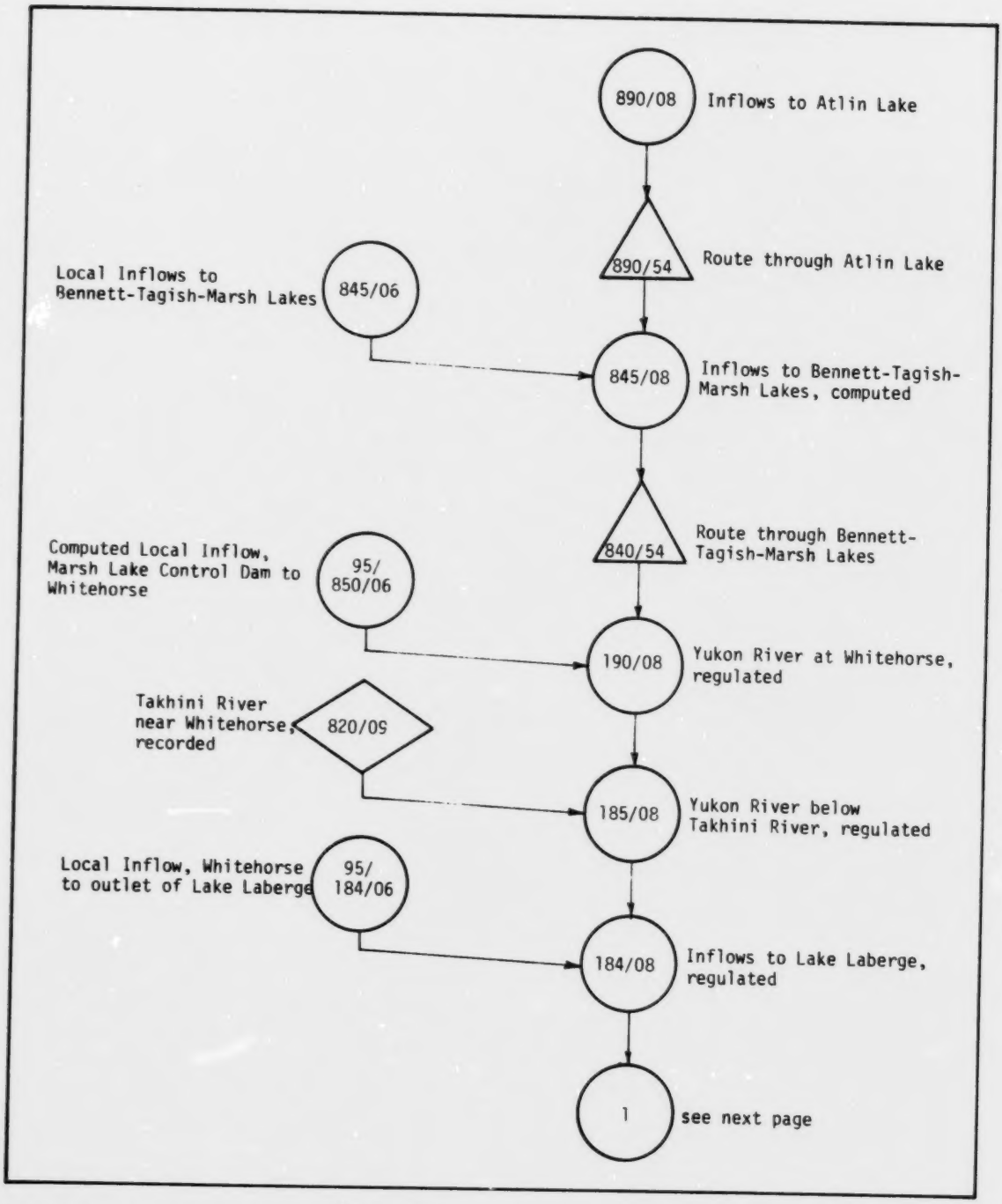


FIGURE 5.5(1): SIMPAK Project Model Flow Chart for Upstream Portion of Yukon River

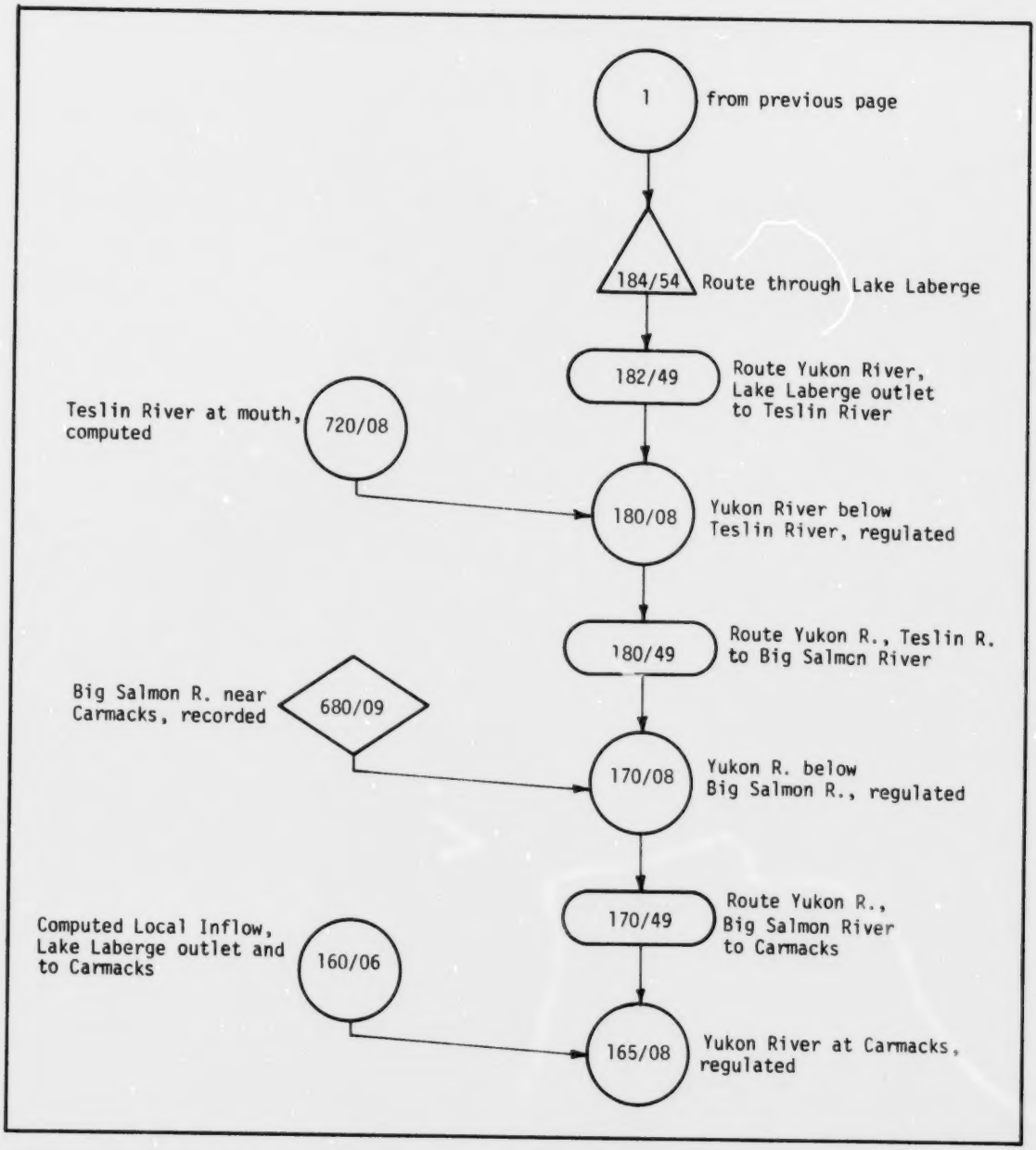


FIGURE 5.5(2): cont'd.

```
YUKON SIMPAK MODEL (MOD.Y21)-PROJECT MODEL FOR UPSTREAM PORTION OF YUKON R.
          89009              1       ATLIN R. NEAR ATLIN, RECORDED
          89054             09       ROUTE THROUTH ATLIN LAKE
          89008              1       INFLOWS TO ATLIN LAKE, COMPUTED
          84506              1       LOCAL INFLOWS TO B-T-M LAKES
          84508              1       TOTAL INFLOWS TO B-T-M LAKES
          84054              9       ROUTE THROUGH B-T-M LAKE
        9585006              1       LOCAL INFLOWS, MARSH LAKE OUTLET TO WHITEHORSE
          19008              1       YUKON R. NEAR WHITEHORSE, COMPUTED
          19009              1       YUKON R. NEAR WHITEHORSE (09AB001), RECORDED
        9019008              1       MARSH LAKE OUTFLOWS, OBSERVED
        9084008              1       MARSH LAKE OUTFLOWS, REGULATED
          82009              1       TAKHINI R. NEAR WHITEHORSE (09AC001), RECORDED
          18508              1       YUKON R. BELOW TAKHINI R. COMPUTED
        9518406              1       LOCAL INFLOWS TO LAKE LABERGE
          18408              1       TOTAL INFLOWS TO LAKE LABERGE
        9518404              0       LAKE LABERGE LEVEL, COMPUTED
          18454              9       ROUTE THROUGH LAKE LABERGE
          18209              1       YUKON R. ABOVE FRANK CREEK (09AB009),RECORDED
          18249              1       ROUTE YUKON R., LAKE LABERGE OUTLET TO TESLIN R.
          72008              1       TESLIN R. NEAR WHITEHORSE, COMPUTED
          18008              1       YUKON R. BELOW TESLIN R., COMPUTED
          18049              1       ROUTE YUKON R., TESLIN R. TO BIG SALMON R.
          68009              1       BIG SALMON R. NEAR CARMACKS (09AG001),RECORDED
          17008              1       YUKON R. BELOW TESLIN R., REGULATED
          17049              1       ROUTE YUKON R., BIG SALMON R. TO CARMACKS
          16006              1       LOCAL INFLOWS, LAKE LABERGE OUTLET TO CARMACKS
          16508              1       YUKON R. AT CARMACKS, COMPUTED
        9016509              1       YUKON R. AT CARMACKS (09AH001), RECORDED
$END
01 05 1964   31 07 1964                1    1                1    1    2
TRSF       89054      89009                                  1 1      1.0
RESE       89054      89008                    -999999999    1 9 9  717356.
ADD        84508      84506       89054                      1 1 1
TRSF       84054     9084008                                  1 1      1.0
RESE       84054      84508                                   1 0 9  850000.       3.49       0.13
ADD        19008      84054     9585006                       1 1 1
ADD        18508      82009       19008                       1 1 1
ADD        18408      18508     9518406                       1 1 1
LAKE       18454      18408
REAC       18249      18454                                   2          0.2        30.0
ADD        18008      18249       72008                       1 1 1
REAC       18049      18008                                   2          0.2        30.0
ADD        17008      18049       68009                       1 1 1
REAC       17049      17008                                   4          0.2        30.0
ADD        16508      17049       16006                       1 1 1
SUBT      9019008     19009     9585006                       1 1 1
WLNR       16508                                              1
PLOT                                                          3
          9019008     1    0          0      1500.
          9084008     1    R          0      1500.
            84054     3    S          0   2500000.
PLOT                                                          2
            18209     1    0          0      1000.
            18454     1    R          0      1000.
PLOT                                                          2
            16508     1    R          0      4000.
          9016509     1    0          0      4000.
$END
$END
```

FIGURE 5.6: SIMPAK Project Model Instructions for Upstream Portion of Yukon River

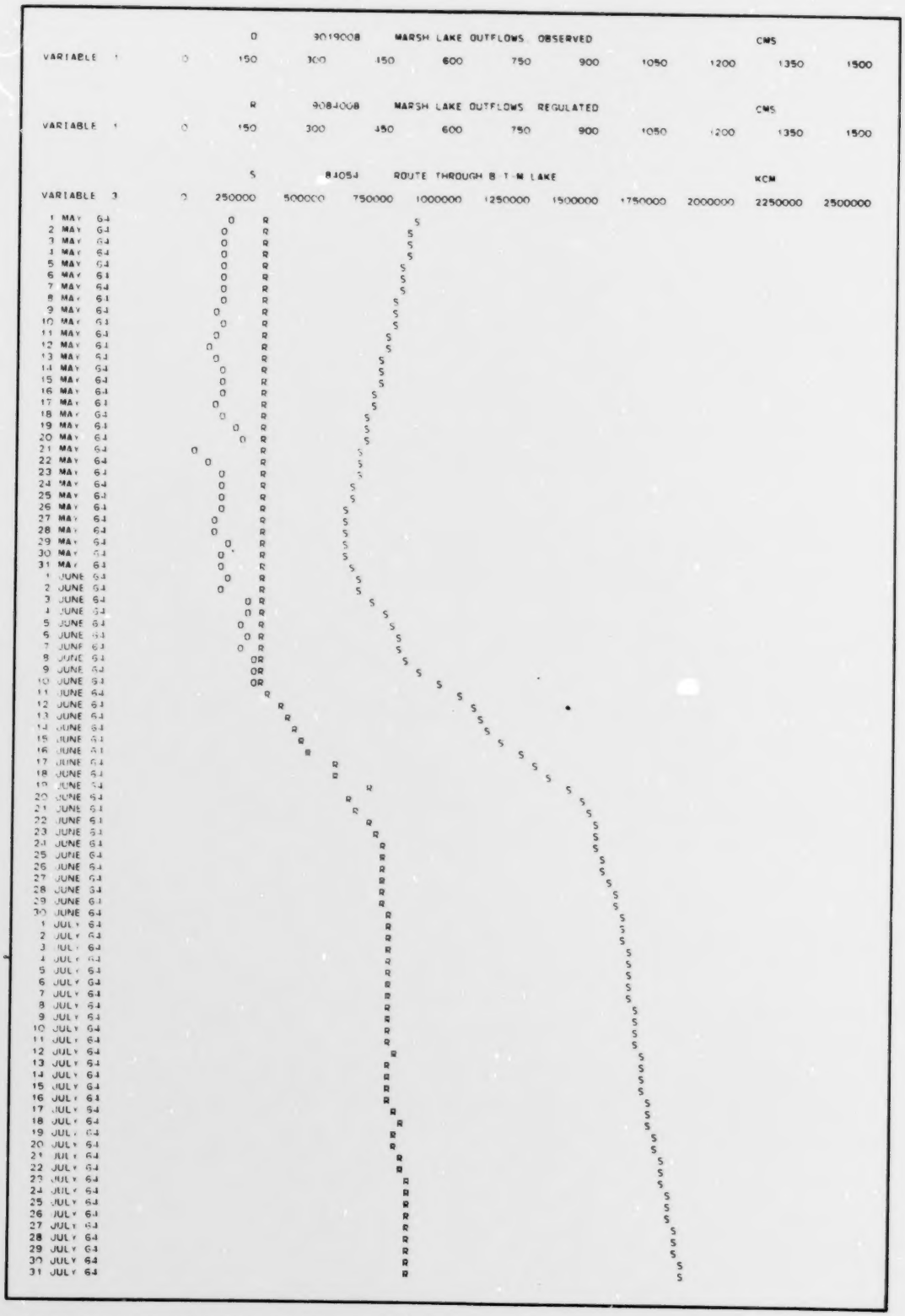


FIGURE 5.7: SIMPAK Plots for Reservoir Regulation at Bennett-Tagish-Marsh Lakes

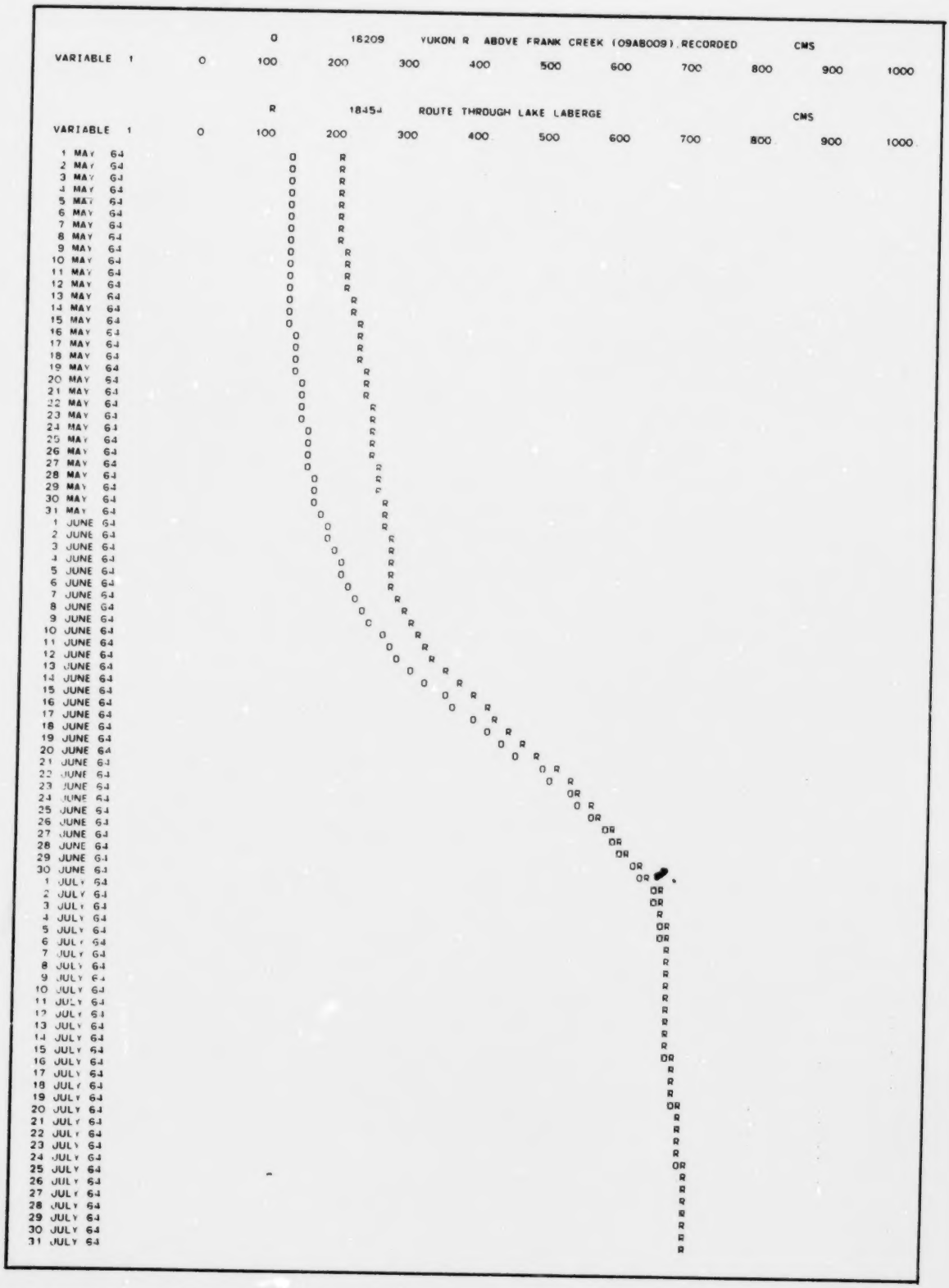


FIGURE 5.8: SIMPAK Plots for Regulation Effect at Outlet of Lake Laberge

CHAPTER 6
DOWNSTREAM PORTION OF YUKON RIVER

This chapter describes the routing model for the downstream portion of the Yukon River. A basin map, flow charts for the project and local inflow models, and a routing parameter summary are provided. The model control instructions and required tables, etc. as well as sample outputs from the model are also included.

6.1 SIMPAK Model for Downstream Portion of Yukon River

The downstream portion of the Yukon Basin Model covers that portion of the river from Carmacks to Eagle, Alaska including major tributaries such as Pelly, White and Stewart Rivers. Figure 6.1 shows a map of that portion of the river basin.

Shown on the map of Figure 6.1 are the WSC hydrometric stations that are used in this model, along with their SIMPAK numbering notation. Table 6.1 lists all the WSC stations used in this model, showing both WSC notation and SIMPAK model notation. Note that the United States Geological Survey's station at Eagle, Alaska is also listed in the table. The Eagle station represents flows at the international border. Although there are WSC gauging stations at the headwaters of the White River and its tributaries, the data provided by these stations is not adequate for the estimation of White River discharges at the mouth which are required as input to both local inflow and project models. To provide estimates of discharges at the mouth of the White River, a set of ratios was derived based on observations from the short period of records and miscellaneous measurements on the White River near the mouth. The White River flows were then estimated by applying the ratios to the computed local inflows between "Yukon River above White River" and "Yukon River at Dawson". Note that these estimates of the White River discharges must be considered as very approximate, prepared mainly to fill a gap in the model. The computed local inflows that were used in this procedure are considered as a balancing factor in the model, to allow a valid

water balance using the recorded data, and are not intended as accurate estimates of the inflowing streams. Because the White River flows were estimated as a portion of the computed local flows, the estimates for White River at the mouth, as computed for this model, must be used with great caution if taken out of context of the model.

The first section of Figure 6.2 shows the SIMPAK model flow chart for computing local inflows from "Pelly River at Ross River" to "Pelly River at Pelly Crossing". The recording of discharges at the Ross River station was discontinued in January 1975. For model use, the period 1975 to 1981 was filled by applying a flow ratio of 0.806 to the station "Pelly River at Vangorda Creek". The second section of Figure 6.2 gives the flow chart for computing local inflows from Carmacks to "Yukon River above White River". Note that the local inflows in this computation do not include flows from "Pelly River at Pelly Crossing". The third section of Figure 6.2 shows the flow chart for computing local inflows from "Yukon River above White River" to "Yukon River at Dawson". The local inflows computed do not include flows at the following locations:

(1) Stewart River at the mouth
(2) White River near the mouth
(3) Klondike River above Bonanza Creek

Note that estimated flows for the White River near the mouth as described above were used as input to this section of the model. The last section of Figure 6.2 shows the flow chart for computing local inflows from Dawson to Eagle, Alaska.

The routing parameters used in local inflow computations are shown in Table 6.2. The control instructions for these local inflow computations for the downstream portion of the Yukon River are given in Figure 6.3. The WLNR operations instruct the SIMPAK program to store the local inflows in long record format for later use by a project model.

A project model flow chart for routing the downstream portion of the Yukon River is shown in Figure 6.4. The model control instructions listed in Figure 6.5 give the configuration for a project model which simulates release patterns for hypothetical reservoirs located at Fortin Lake and Hoole Canyon on the Pelly River. Tables 6.3 and 6.4 list storage tables for the reservoirs. In this example inflows were routed through the hypothetical reservoirs and outflows were controlled to provide firm flow releases of 42.5 and 56.6 cubic metres per second for Fortin Lake and Hoole Canyon respectively. It should be noted that in this sample run the recorded flows at station 9016509 were used instead of the regulated flows at station 16508 as shown in Figure 6.4. This was necessary because the regulated flows were not available at the time of the run. Figure 6.6 shows computer plots from runs simulating reservoir regulation at Fortin Lake and Figure 6.7 shows the same for the Hoole Canyon reservoir. A comparison of the recorded natural flows and regulated flows for "Pelly River at Pelly Crossing" is given in Figure 6.8, showing the effect of regulation by Fortin Lake and Hoole Canyon reservoirs.

In the example noted above, the Stewart River has not been included in the model except for the input of natural flows at station 9031009. A segment for the model covering the Stewart River from Mayo to the mouth has also been developed. This segment is described in the schematic diagrams of Figures 6.9 and 6.10. The routing parameters for this portion of the model are included in Table 6.2.

The Stewart River from Mayo to the mouth is a 250 kilometre stretch of river having a fairly constant slope of 0.5 metres per kilometre. For modelling purposes, this stretch of river was considered as nine separate sub-reaches, each having similar routing characteristics and each being about fifty kilometres long. There are two of these sub-reaches between Mayo and Stewart Crossing, two between Stewart Crossing and the McQuesten River junction, and five between McQuesten and the mouth. Local inflows are computed at Stewart Crossing and at the mouth.

The Stewart River project model given in Figure 6.10 shows the natural river and does not include any projects. A project can be added to this model by replacing the station (or several stations), representing the portion of the river to be altered by the project, with operations to simulate the characteristics of the project. The Stewart River portion of the model can be appended to the downstream model by replacing station 9031009 with station 31008 and including other stations for the Stewart River portion in the model control data preceding station 31008.

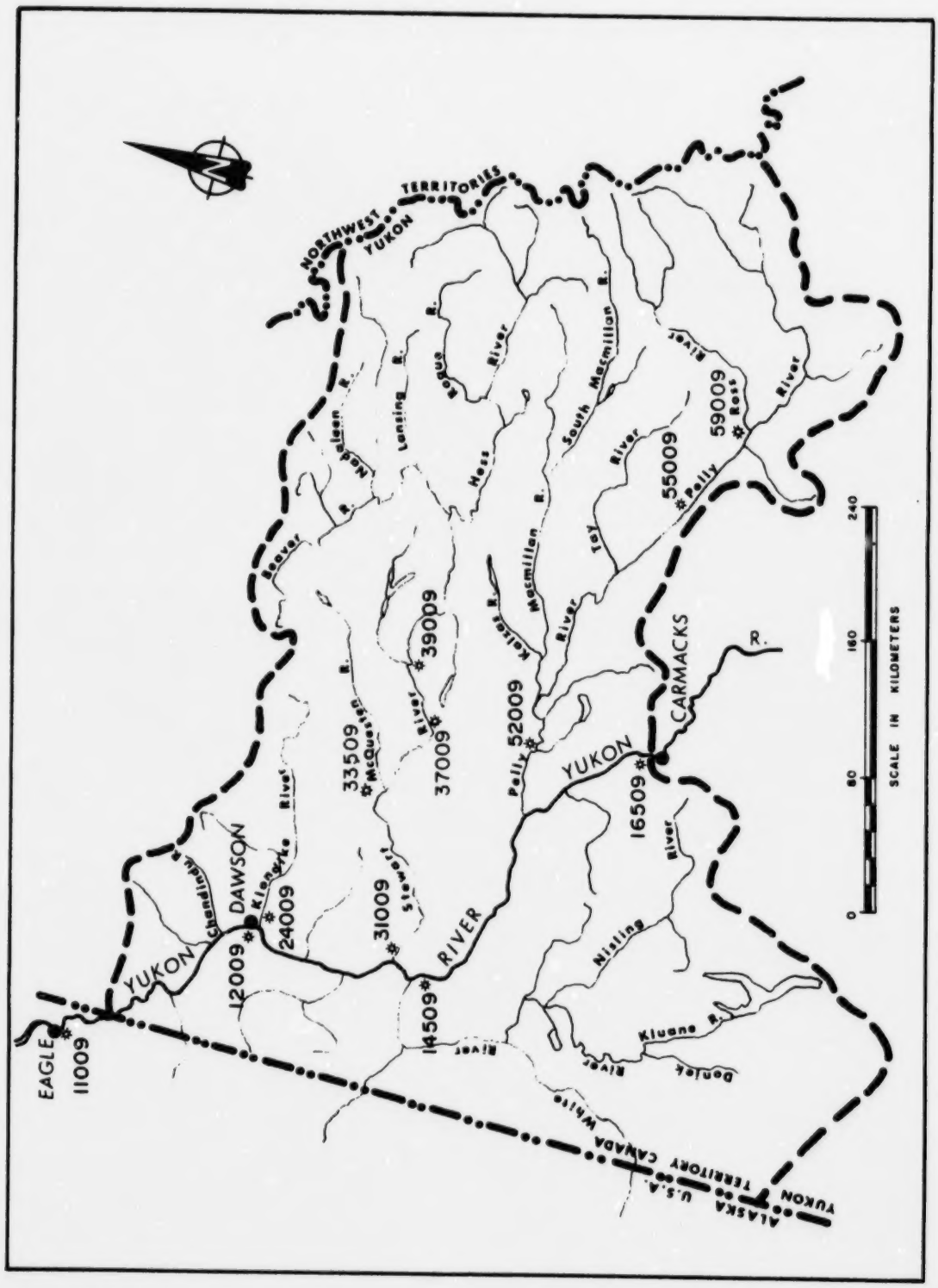


FIGURE 6.1: Map of Downstream Portion of Yukon River Basin

Table 6.1: Gauging Stations Required for Routing Downstream Portion of Yukon River

Gauging Station	WSC Number	SIMPAK Number
Yukon River at Carmacks	09AH001	16509
Pelly River at Ross River	09BC002	59009
Pelly River below Vangorda Creek	09BC004	55009
Pelly River at Pelly Crossing	09BC001	52009
Yukon River above White River	09CD001	14509
Stewart River at Mayo	09DC002	39009
Stewart River at Stewart Crossing	09DD002	37009
McQuesten River near the mouth	09DD004	33509
Stewart River at the mouth	09DD003	31009
Klondike River above Bonanza Creek	09EA003	24009
Yukon River at Dawson	09EB001	12009
Yukon River at Eagle, Alaska	N/A	11009

Note: A "90" or "95" is prefixed to SIMPAK number if the station data has been extended or computed.

Table 6.2: SIMPAK Model Routing Parameters for Downstream Portion of Yukon River

Yukon River below Carmacks	SIMPAK Number	Routing Parameters		
		Phases	n	KTS
Pelly R., Ross River to Vangorda Creek	55049	4	0.2	40
Pelly R., Vangorda Creek to Pelly Crossing	53049	4	0.2	40
Pelly R., Pelly Crossing to the mouth	52049	1	0.2	30
Yukon R., Carmacks to Minto	16549	2	0.2	30
Yukon R., Minto to Fort Selkirk	16049	1	0.2	30
Yukon R., Fort Selkirk to Coffee Creek	15049	3	0.2	30
Yukon R., Coffee Creek to White River	14549	2	0.2	30
Stewart R., Mayo to Stewart Crossing	37049	2	0.2	25
Stewart R., Stewart Crossing to McQuesten R.	33049	2	0.2	25
Stewart R., McQuesten R. to the mouth	31049	5	0.2	25
Yukon R., White River to Indian River	13049	4	0.2	15
Yukon R., Indian River to Dawson	12049	3	0.2	15
Yukon R., Dawson to Eagle, Alaska	11049	4	0.2	40

Table 6.3: Storage Table for Fortin Lake

Sequence Number	Elevation (metres)	Storage (1000 cubic metres)
1	877.96	0
2	879.50	38 000
3	880.00	54 000
4	881.50	120 000
5	884.00	270 000
6	886.90	500 000
7	888.50	630 000
8	890.00	780 000
9	891.00	863 000
10	891.50	910 000
11	900.00	1 950 000

Table 6.4: Storage Table for Hoole Canyon Reservoir

Sequence Number	Elevation (metres)	Storage (1000 cubic metres)
1	780.00	60 000
2	785.00	100 000
3	787.70	129 000
4	790.00	158 000
5	794.50	234 000
6	800.00	327 000

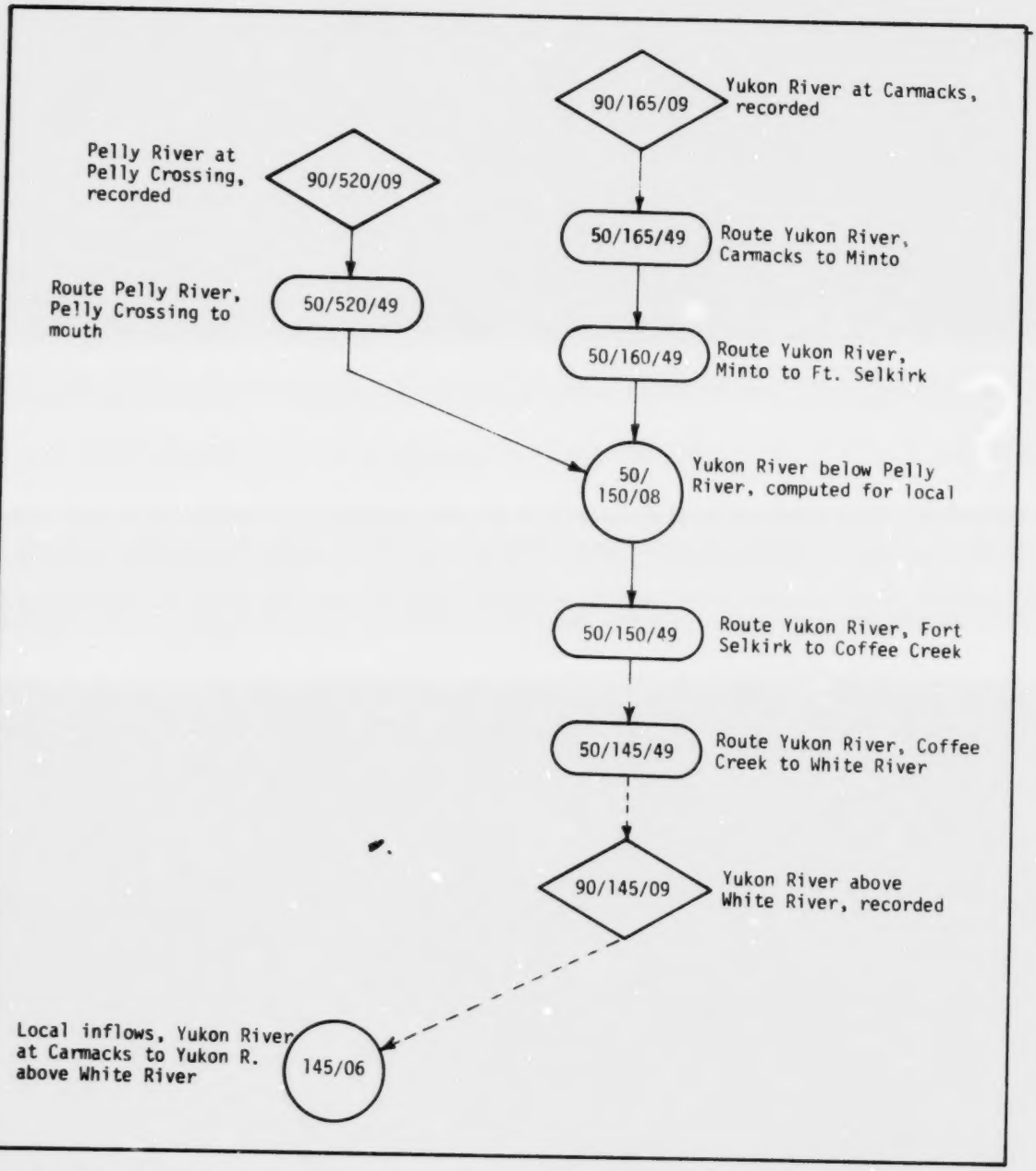

90/165/09
Yukon River at Carmacks, recorded
Pelly River at Pelly Crossing, recorded
90/520/09
50/165/49
Route Yukon River, Carmacks to Minto
Route Pelly River, Pelly Crossing to mouth
50/520/49
50/160/49
Route Yukon River, Minto to Ft. Selkirk
50/ 150/08
Yukon River below Pelly River, computed for local
50/150/49
Route Yukon River, Fort Selkirk to Coffee Creek
50/145/49
Route Yukon River, Coffee Creek to White River
90/145/09
Yukon River above White River, recorded
Local inflows, Yukon River at Carmacks to Yukon R. above White River
145/06

FIGURE 6.2(1): SIMPAK Local Model Flow Chart for Downstream Portion of Yukon River

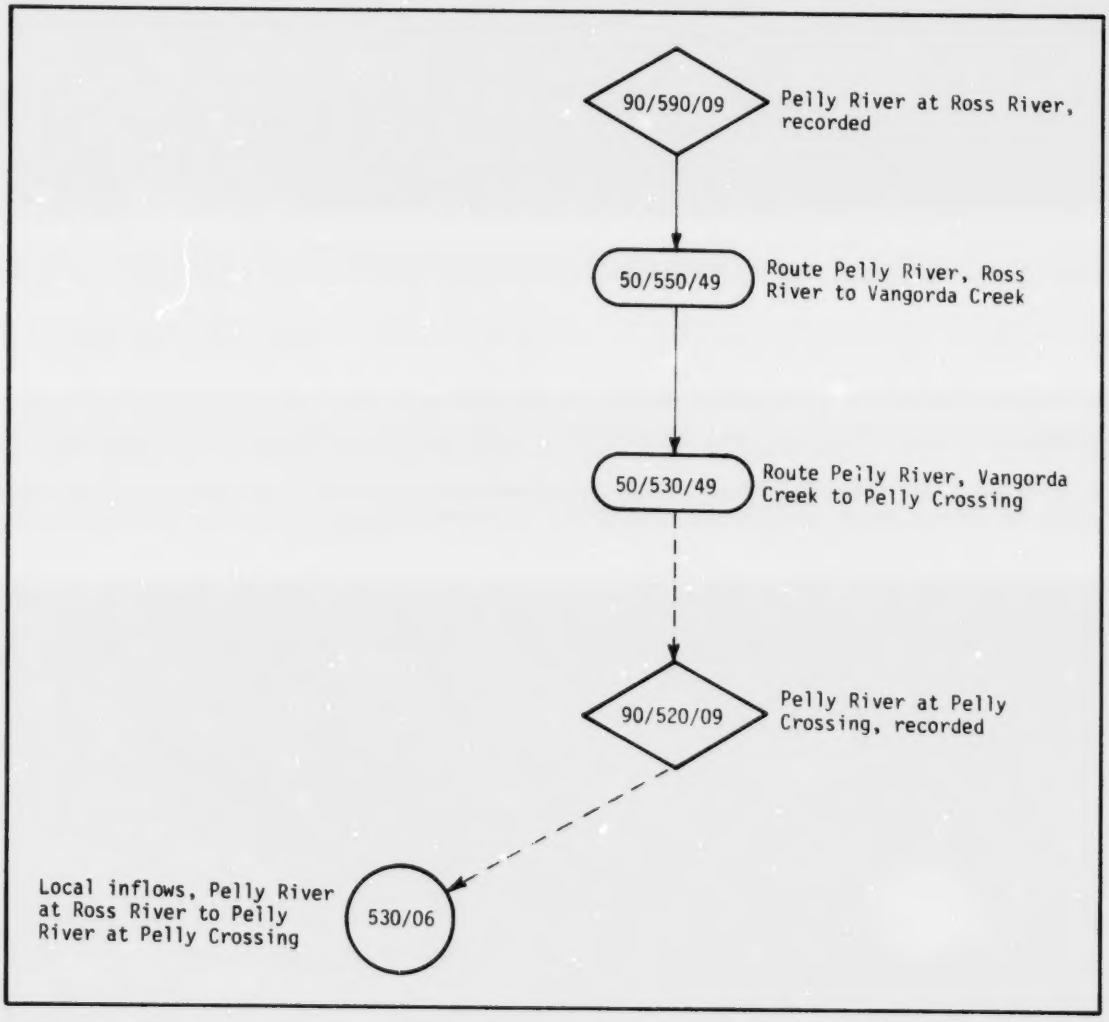

90/590/09
Pelly River at Ross River, recorded
50/550/49
Route Pelly River, Ross River to Vangorda Creek
50/530/49
Route Pelly River, Vangorda Creek to Pelly Crossing
90/520/09
Pelly River at Pelly Crossing, recorded
Local inflows, Pelly River at Ross River to Pelly River at Pelly Crossing
530/06

FIGURE 6.2(2): cont'd.

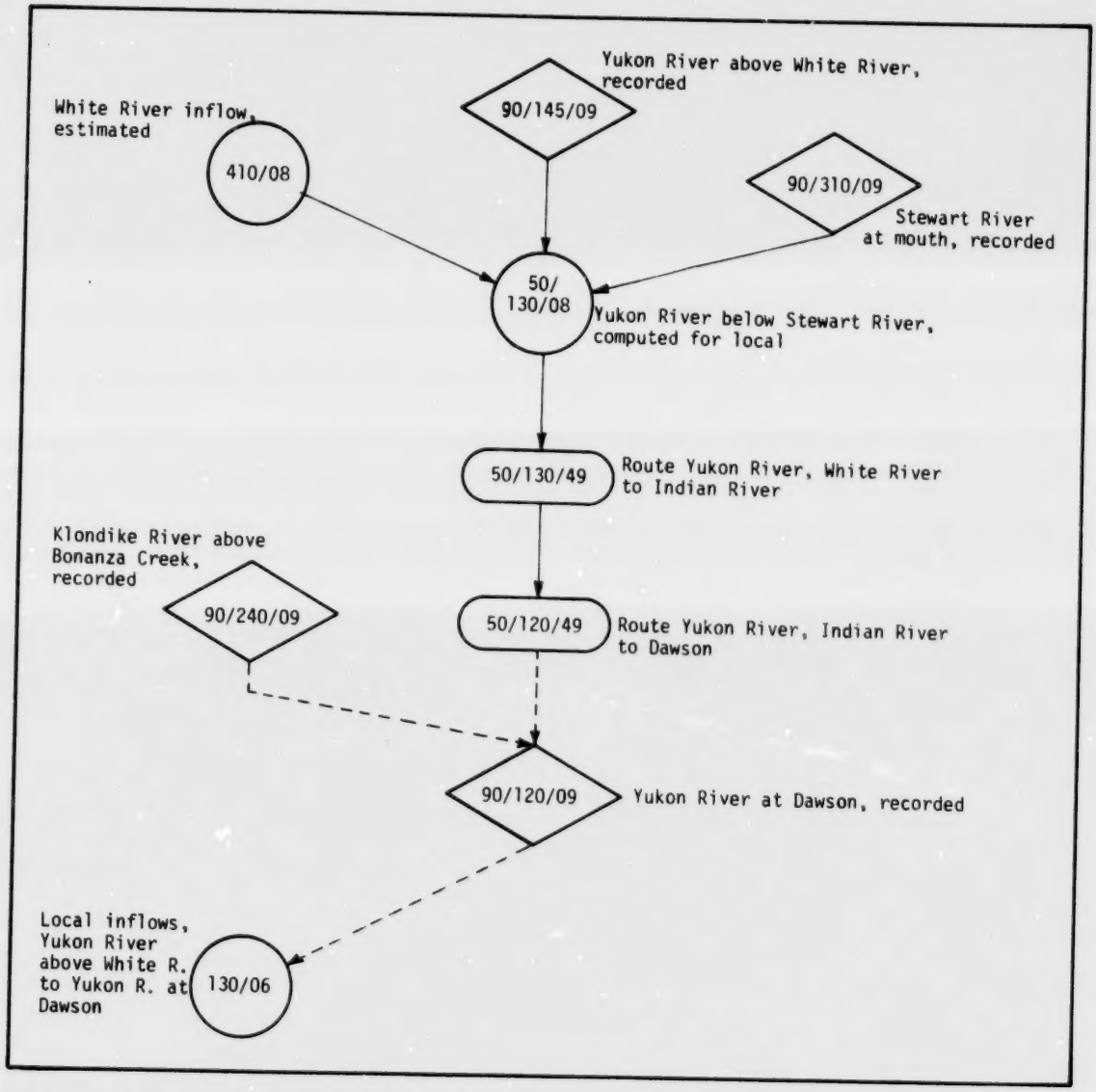


FIGURE 6.2(3): cont'd.

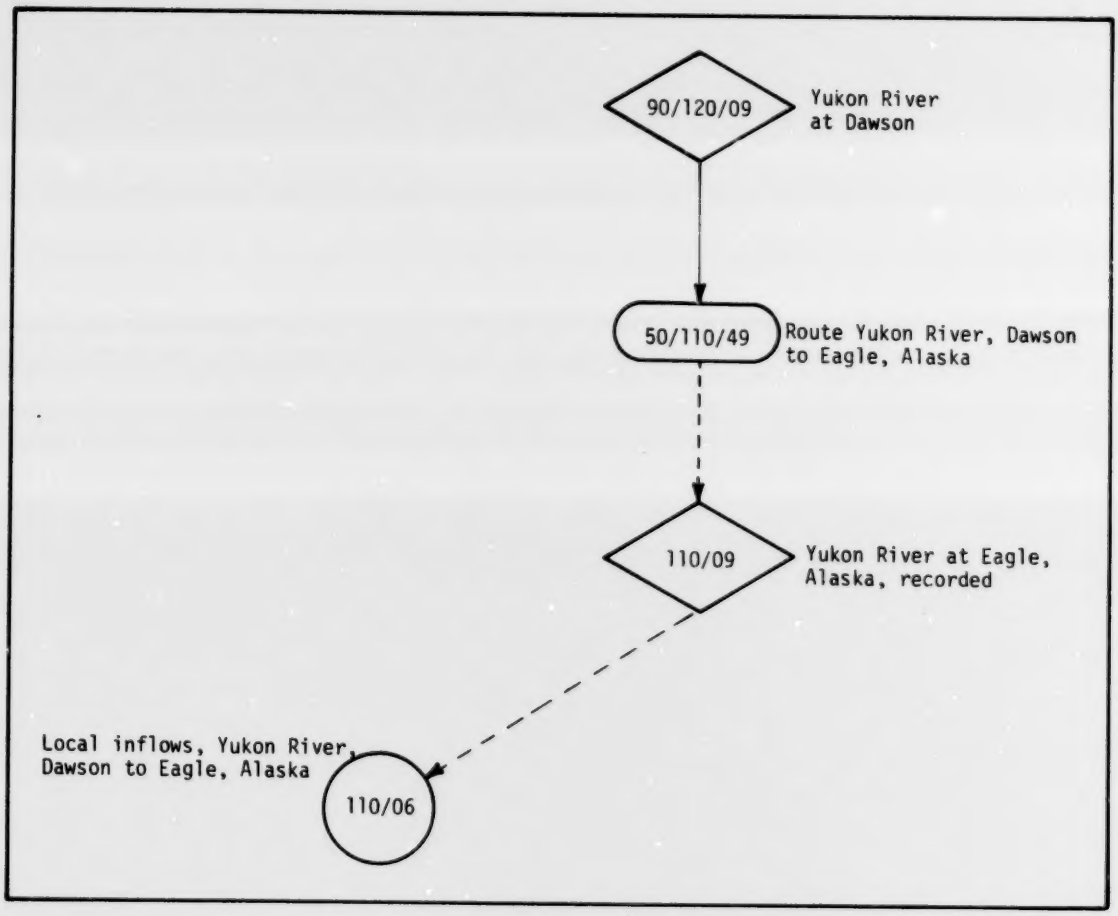


FIGURE 6.2(4): cont'd.

```
YUKON SIMPAK MODEL (SUB-MODEL MOD Y4A 1)-LOCAL INFLOW, PELLY R  AT ROSS R  TO PELLY CROSSING
      9059009            1      PELLY R AT ROSS R (09BC002), RECORDED
      5055049            1      ROUTE PELLY R , ROSS R  TO VANGORDA CREEK
      5053049            1      ROUTE PELLY R , VANGORDA CREEK TO PELLY CROSSING
      9052009            1      PELLY R AT PELLY CROSSING (09BC001), RECORDED
        53006            1      LOCAL INFLOWS, PELLY R  AT ROSS R  TO PELLY CROSSING
$END
01 01 1964  31 12 1964                                        1    1    2
REAC    5055049   9059009                              4          0 2       40 0
REAC    5053049   5055049                              4          0 2       40 0
SUBT      53006   9052009   5053049                    1 1 1
WLNR      53006                                        1
$END
$END


YUKON SIMPAK MODEL (SUB-MODEL MOD Y4 1) - LOCAL INFLOWS, YUKON R  AT CARMACKS TO WHITE R
      9016509            1      YUKON R  AT CARMACKS (09AH001), RECORDED
      9052009            1      PELLY R  AT PELLY CROSSING (09BC001), RECORDED
      9014509            1      YUKON R  ABOVE WHITE R  (09CD001), RECORDED
      5016549            1      ROUTE YUKON R , CARMACKS TO MINTO
      5016049            1      ROUTE YUKON R , MINTO TO FT  SELKIRK
      5052049            1      ROUTE PELLY R , PELLY CROSSING TO MOUTH
      5015008            1      YUKON R  BELOW PELLY R
      5015049            1      ROUTE YUKON R , FT  SELKIRK TO COFFEE CREEK
      5014549            1      ROUTE YUKON R , COFFEE CREEK TO WHITE R
        14506            1      LOCAL INFLOWS, YUKON R  AT CARMACKS TO WHITE R
$END
01 01 1964  31 12 1964                                        1    1    2
REAC    5016549   9016509                              2          0 2       30 0
REAC    5016049   5016549                              1          0 2       30 0
REAC    5052049   9052009                              1          0 2       30 0
ADD     5015008   5016049   5052049                    1 1 1
REAC    5015049   5015008                              3          0 2       30 0
REAC    5014549   5015049                              2          0 2       30 0
SUBT      14506   9014509   5014549                    1 1 1
WLNR      14506                                        1
$END
$END


YUKON SIMPAK MODEL (SUB- MODEL MOD Y5) - LOCAL INFLOWS, YUKON R  ABOVE WHITE  R  TO DAWSON
        13006            1      LOCAL INFLOWS, YUKON R  ABOVE WHITE R  TO DAWSON
      9024009            1      KLONDIKE R  ABOVE BONANZA CREEK, RECORDED
      9014509            1      YUKON R  ABOVE WHITE R  (09CD001), RECORDED
      9031009            1      STEWART R  AT THE MOUTH (09DD003), RECORDED
      9012009            1      YUKON R  AT DAWSON (09EB001), RECORDED
        41008            1      WHITE R  INFLOWS ESTIMATED BY RATIO
      5013008            1      YUKON R  BELOW STEWART R , COMPUTED
      5013049            1      ROUTE YUKON R , WHITE R  TO INDIAN R
      5012049            1      ROUTE YUKON R , INDIAN R  TO DAWSON
$END
01 01 1964  31 12 1964                                        1    1    2
ADD     5013008     41008   9014509   9031009 1 1 1
REAC    5013049   5013008                              4          0 2       15 0
REAC    5012049   5013049                              3          0 2       15 0
SUBT      13006   9012009   5012049   9024009 1 1 1
WLNR      13006                                        1
$END
$END


YUKON SIMPAK MODEL (SUB-MODEL MOD Y6) - LOCAL INFLOWS, YUKON R  AT DAWSON TO EAGLE, ALASKA
      9012009            0      YUKON R  AT DAWSON (09EB001), RECORDED
      5011049            0      YUKON R  AT DAWSON ROUTED TO BORDER
        11009            0      YUKON R  AT EAGLE (U S  STATION), RECORDED
        11006            0      LOCAL INFLOWS, YUKON R  AT DAWSON TO EAGLE, ALASKA
$END
01 01 1960  31 12 1981                                        1    1    2
REAC    5011049   9012009                              4          0 2       40
SUBT      11006     11009   5011049                    1 1 1
WLNR      11006                                        1
$END
$END
```

FIGURE 6.3: SIMPAK Local Model Instructions for Downstream Portion of Yukon River

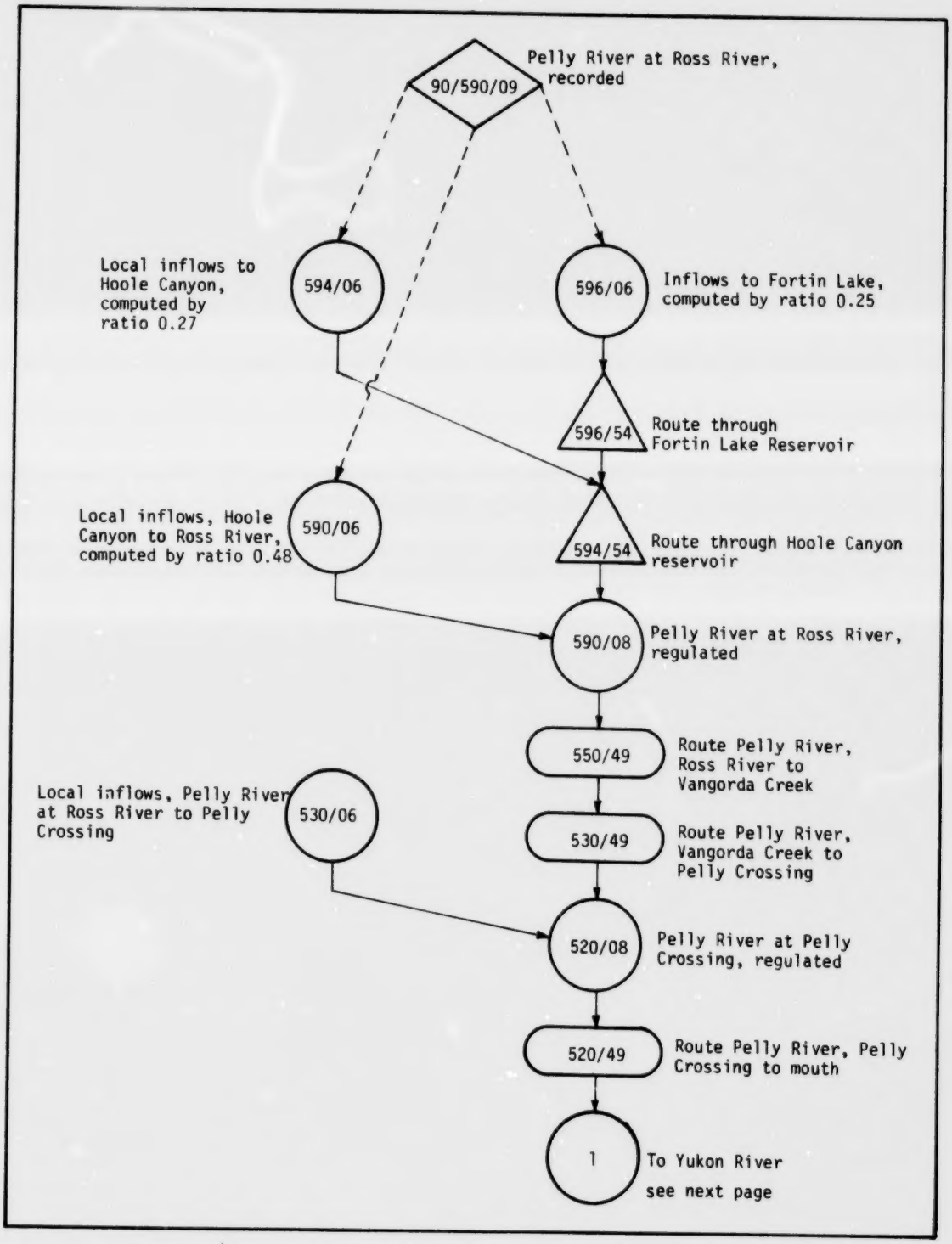

90/590/09
Pelly River at Ross River, recorded
Local inflows to Hoole Canyon, computed by ratio 0.27
594/06
596/06
Inflows to Fortin Lake, computed by ratio 0.25
596/54
Route through Fortin Lake Reservoir
Local inflows, Hoole Canyon to Ross River, computed by ratio 0.48
590/06
594/54
Route through Hoole Canyon reservoir
590/08
Pelly River at Ross River, regulated
550/49
Route Pelly River, Ross River to Vangorda Creek
Local inflows, Pelly River at Ross River to Pelly Crossing
530/06
530/49
Route Pelly River, Vangorda Creek to Pelly Crossing
520/08
Pelly River at Pelly Crossing, regulated
520/49
Route Pelly River, Pelly Crossing to mouth
1
To Yukon River
see next page

FIGURE 6.4(1): SIMPAK Project Model Flow Chart for Downstream Portion of Yukon River

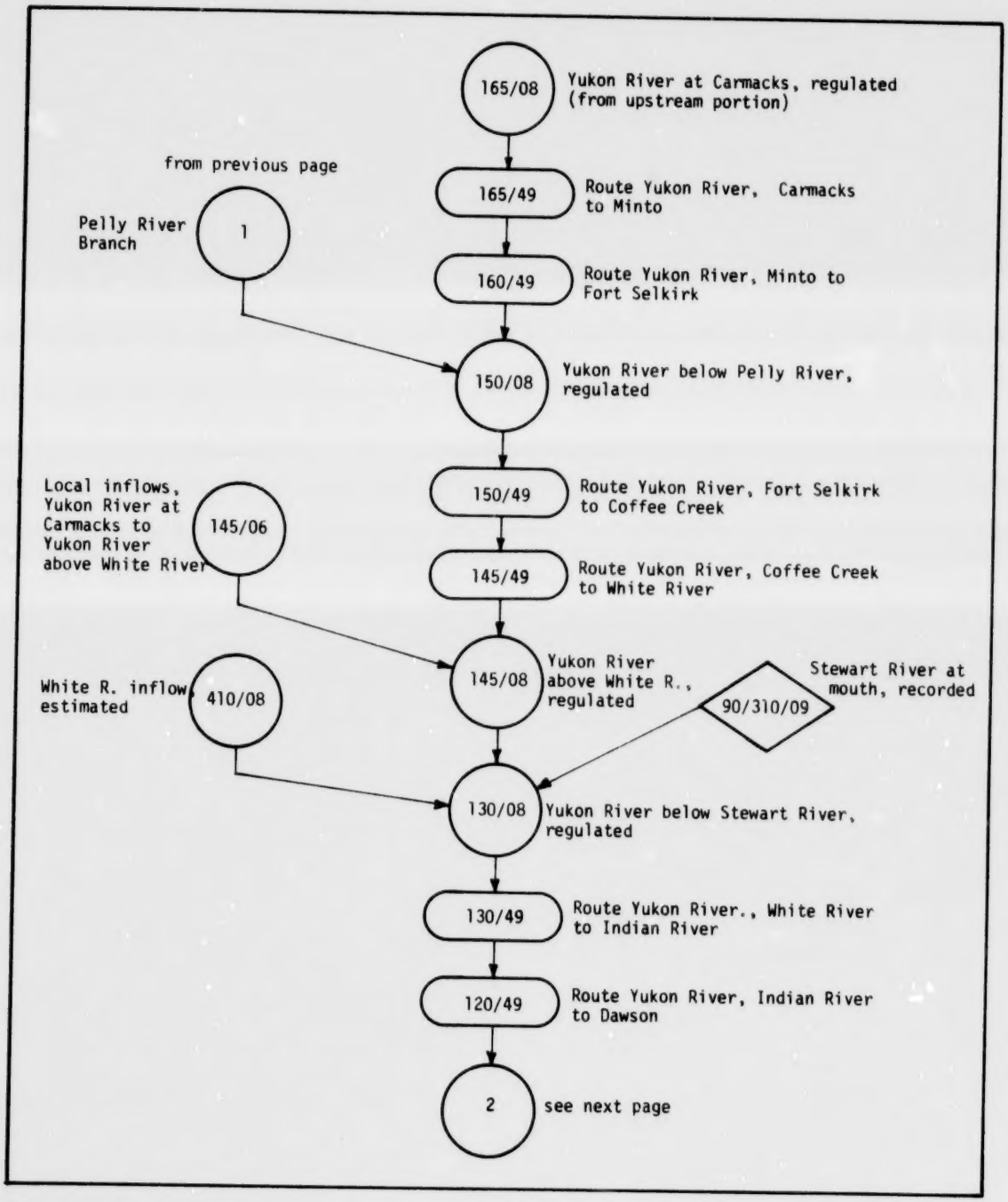


FIGURE 6.4(2): cont'd.

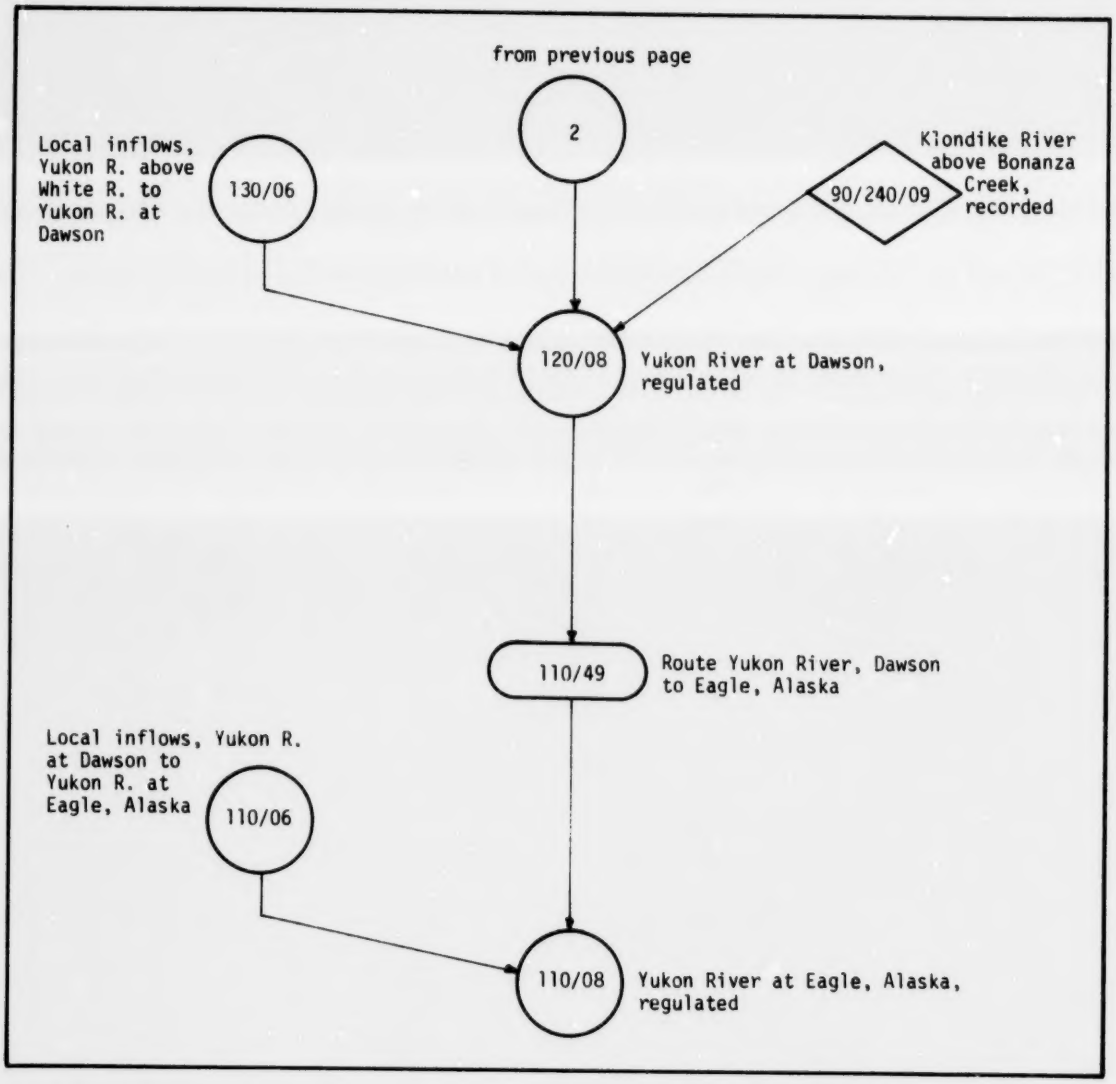

from previous page
2
Local inflows, Yukon R. above White R. to Yukon R. at Dawson
130/06
Klondike River above Bonanza Creek, recorded
90/240/09
120/08
Yukon River at Dawson, regulated
110/49
Route Yukon River, Dawson to Eagle, Alaska
Local inflows, Yukon R. at Dawson to Yukon R. at Eagle, Alaska
110/06
110/08
Yukon River at Eagle, Alaska, regulated

FIGURE 6.4(3): cont'd.

```
YUKON SIMPAK MODEL(MOD.Y33) - REGULATION AT HOOLE CANYON PROJECT
      9016509          00 0    YUKON R. AT CARMACKS (09AH001), RECORDED
        16549           0       ROUTE YUKON R., CARMACKS TO MINTO
        16049           0       ROUTE YUKON R., MINTO TO PELLY R.(FT. SELKIRK)
      9059009          00       PELLY R. AT ROSS R.(09BC002), RECORDED
        59006           0       LOCAL INFLOWS, HOOLE CANYON TO ROSS R.
        59406           0       LOCAL INFLOWS TO HOOLE CANYON RES.
        59606           0       INFLOWS TO FORTIN LAKE RES.
        59654           9       ROUTE THROUGH FORTIN LAKE RES.
        59454           9       ROUTE THROUTH HOOLE CANYON RES.
        59008           0       PELLY R. AT ROSS R., REGULATED
        55049           0       ROUTE PELLY R., ROSS RIVER TO VANGORDA CREEK
        53049           0       ROUTE PELLY R., VANGORDA CREEK TO PELLY CROSSING
        53006           0       LOCAL INFLOWS, AT ROSS R. TO PELLY CROSSING
        52008           0       PELLY R. AT PELLY CROSSING, REGULATED
      9052009          00       PELLY R. AT PELLY CROSSING (09BC001), RECORDED
        52049           0       ROUTE PELLY R., PELLY CROSSING TO MOUTH
        15008           0       YUKON R. BELOW PELLY R.,REGULATED
        14506           0       LOCAL INFLOW, CARMACKS TO YUKON ABOVE WHITE R.
        15049           0       ROUTE YUKON R., FT. SELKIRK TO COFFEECR.
        14549           0       ROUTE YUKON R., COFFEE CREEK TO WHITE R.
        14508           0       YUKON R. ABOVE WHITE R., REGULATED
      9031009          00       STEWART R. AT MOUTH (09DD003), RECORDED
        41008           0       WHITE R. AT MOUTH, ESTIMATED
        13008          00       YUKON R. AT STEWART R., REGULATED
        13049           0       ROUTE YUKON R., WHITE R. TO INDIAN R.
        12049           0       ROUTE YUKON R., INDIAN R. TO DAWSON
      9012009          00       YUKON R. AT DAWSON (09EB001), RECORDED
        12008          00       YUKON R. AT DAWSON, REGULATED
        13006           0       LOCAL INFLOW, STEWART R. TO DAWSON
        11049           0       ROUTE YUKON R., DAWSON TO EAGLE
        11009          00       YUKON R. AT EAGLE (ALASKA), RECORDED
        11008          00       YUKON R. AT EAGLE (ALASKA), REGULATED
        11006           0       LOCAL INFLOW, DAWSON TO EAGLE
      9024009          00       KLONDIKE R. ABOVE BONANZA CR., RECORDED
$END
01 05 1964  31 07 1964          0    1                1    1    2
REAC      16549    9016509                        2          0.2          30
REAC      16049      16549                        1          0.2          30
TRSF      59006    9059009                        1 1        0.48
TRSF      59406    9059009                        1 1        0.27
TRSF      59606    9059009                        1 1        0.25
SET       59654                                   1         62.48
SET       59454                                   1         56.63
RESE      59654      59606                        1 0 9  110000.      891.0      879.5
RESE      59454      59654    59406               1 0 9  142000.      794.5      787.7
ADD       59008      59454    59006               1 1 1
REAC      55049      59008                        4          0.2       40.
REAC      53049      55049                        4          0.2       40.
ADD       52008      53049    53006               1 1 1
REAC      52049      52008                        1          0.2          30
ADD       15008      16049    52049               1 1 1
REAC      15049      15008                        3          0.2          30
REAC      14549      15049                        2          0.2          30
ADD       14508      14549    14506               1 1 1
ADD       13008      41008    14508    9031009    1 1 1
REAC      13049      13008                        4          0.2          15
REAC      12049      13049                        3          0.2          15
ADD       12008      13006    12049    9024009    1 1 1
REAC      11049      12008                        4          0.2          40
ADD       11008      11049    11006               1 1 1
PLOT                                              3
          59606    1    N         0       800.
          59654    1    R         0       800.
          59654    3    S         0    910000.
PLOT                                              3
          59406    1    N         0      1200.
          59454    1    R         0      1200.
          59454    3    S         0    300000.
PLOT                                              2
        9052009    1    0         0      5000.
          52008    1    R         0      5000.
$END
$END
```

FIGURE 6.5: SIMPAK Project Model Instructions for Downstream Portion of Yukon River

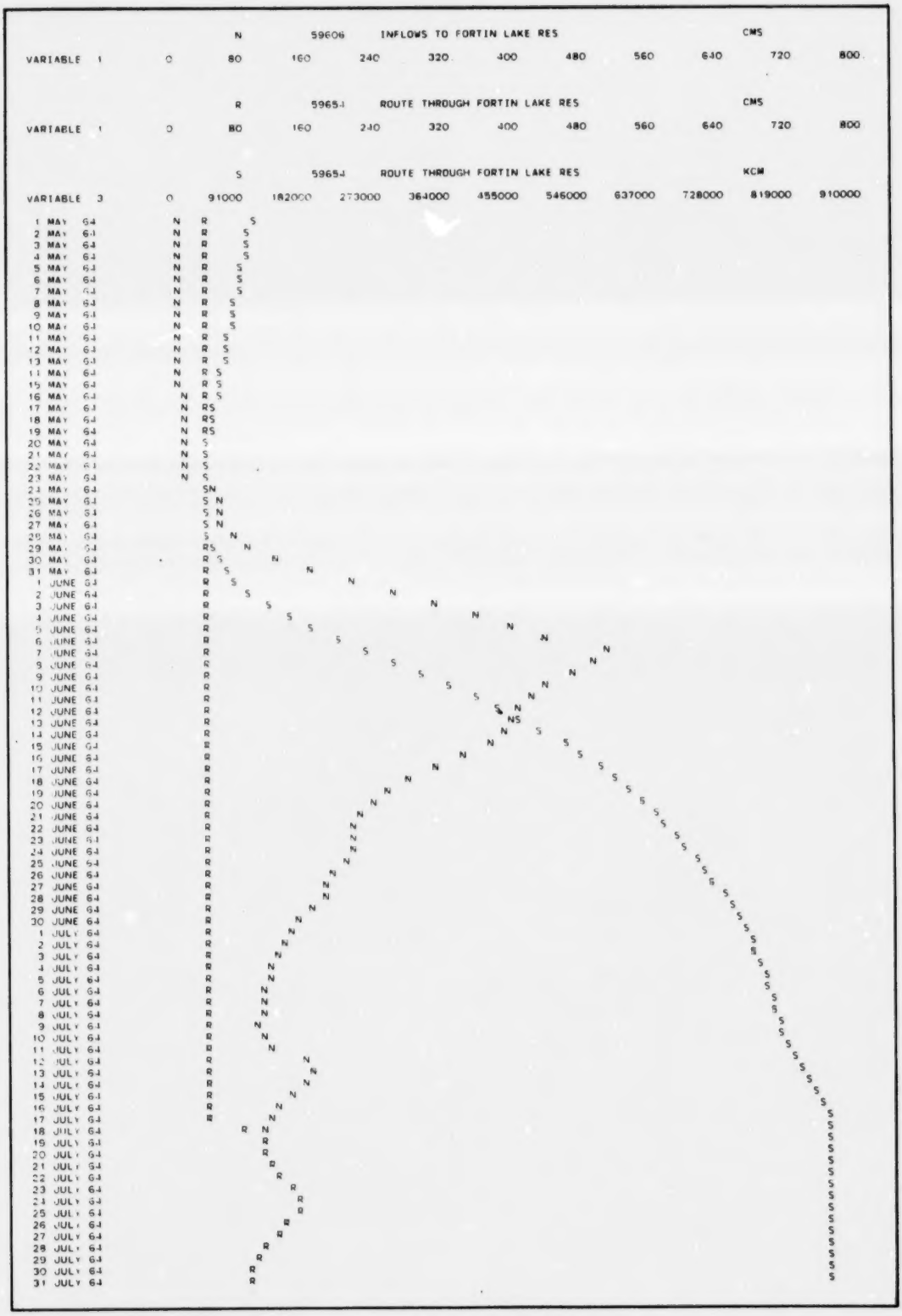


FIGURE 6.6: SIMPAK Plots for Reservoir Regulation at Fortin Lake

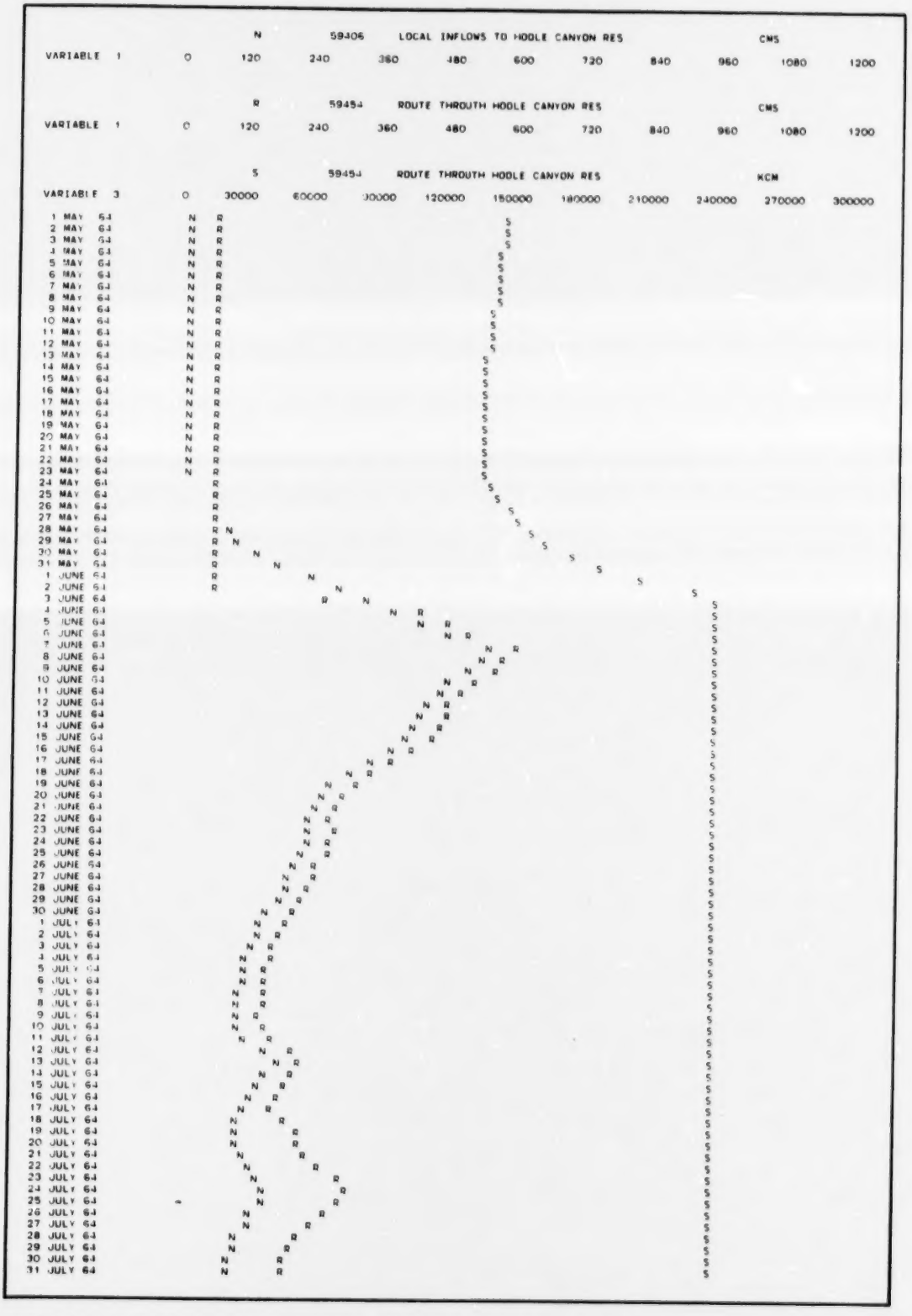


FIGURE 6.7: SIMPAK Plots for Reservoir Regulation at Hoole Canyon

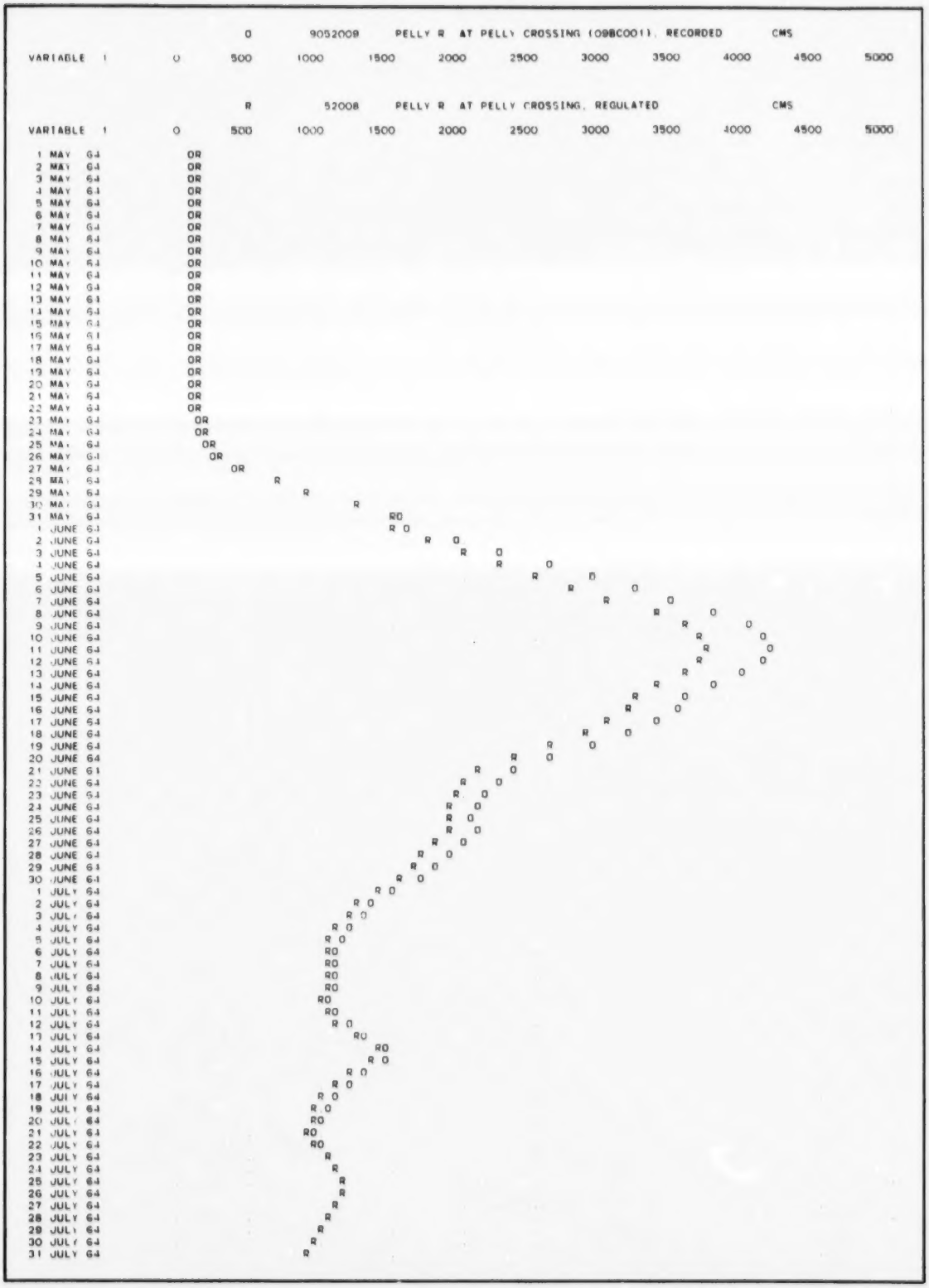


FIGURE 6.8: SIMPAK Plots for Regulation Effect at Pelly River at Pelly Crossing

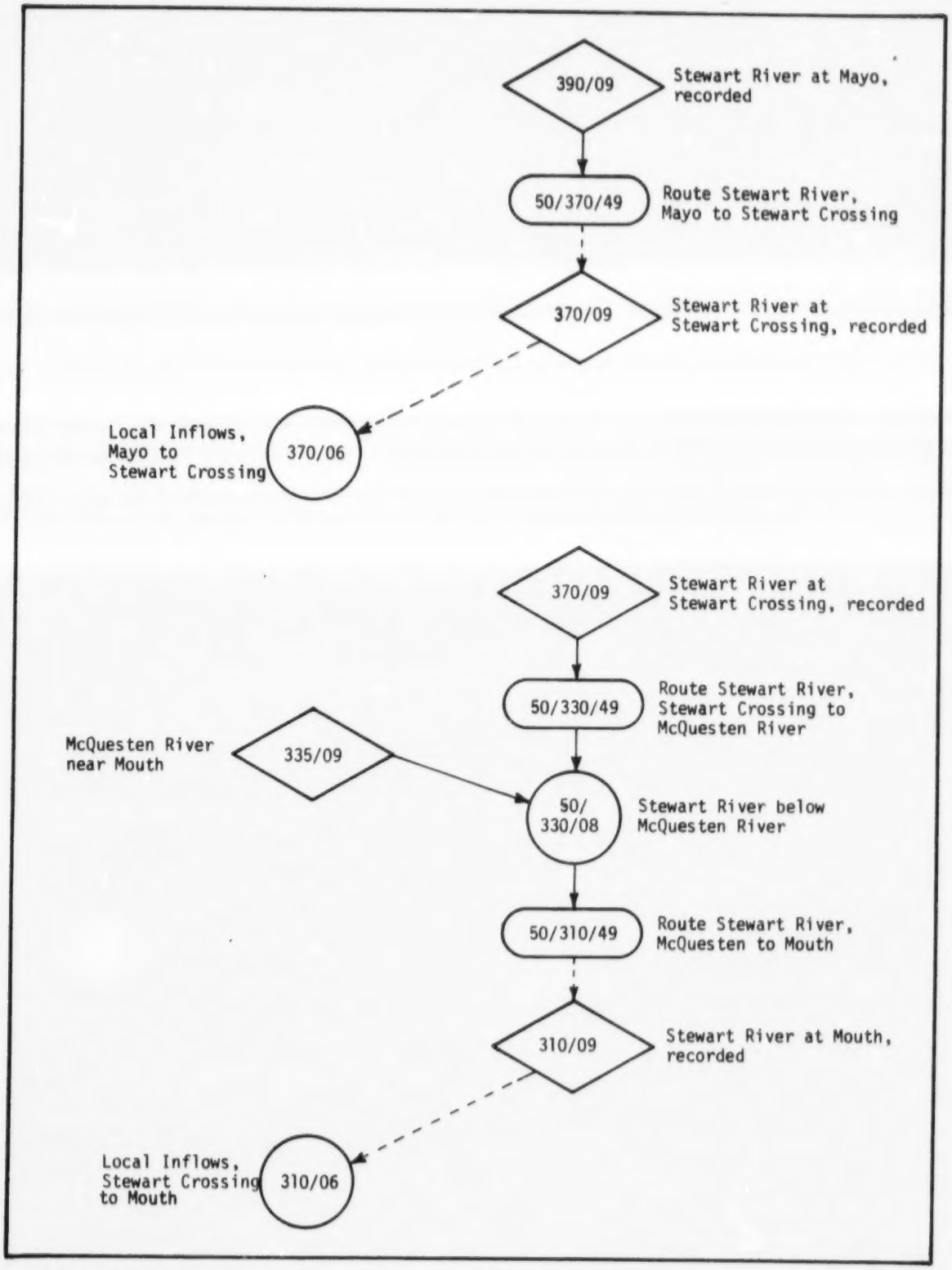
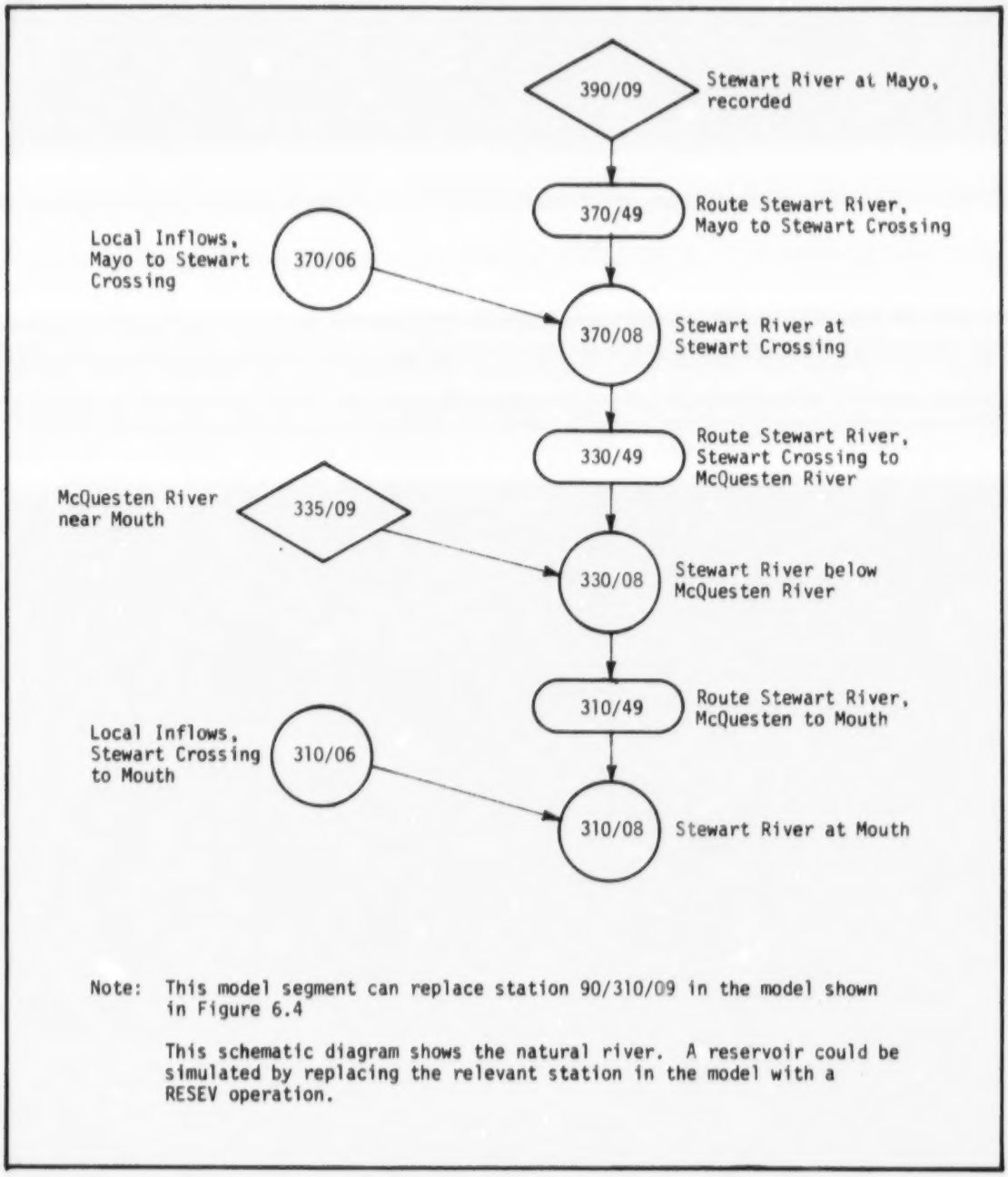


FIGURE 6.9: SIMPAK Local Model Flow Chart for Stewart River



Note: This model segment can replace station 90/310/09 in the model shown in Figure 6.4

This schematic diagram shows the natural river. A reservoir could be simulated by replacing the relevant station in the model with a RESEV operation.

FIGURE 6.10: SIMPAK Project Model Flow Chart for Stewart River

REFERENCES

1. Inland Waters Directorate, Pacific and Yukon Region, Vancouver, B.C. "SIMPAK User's Manual." Updated manual under preparation by IWD, previous version available from IWD, Pacific & Yukon Region.

2. Mackenzie River Basin Committee. "Daily Hydrologic Model User Manual." Mackenzie River Basin Study Report, Supplement 8. 1981.

3. U.S. Army Engineer Division, North Pacific, Portland, Oregon. "Program Description and User Manual for SSARR Model, Streamflow Synthesis and Reservoir Regulation." Program 724-K5-G0010. December 1972.

4. Wilson, W.T. "A Graphical Flood Routing Method." Transactions, American Geophysical Union, Part II. 1941.

APPENDIX A

Yukon River
Daily Hydrologic Model

YUKON RIVER BASIN STUDY

Hydrology Project #44

FIELD SURVEYS FOR THE YUKON HEADWATER LAKES

August 1982

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Water Planning and Management Branch
Inland Waters Directorate
Pacific and Yukon Region
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FIELD SURVEYS FOR THE YUKON HEADWATER LAKES

August 1982

Introduction

In developing the "Daily Hydrologic Flow Simulation Model" as a part of the hydrology program of the Yukon River Basin Study, it was necessary to determine the characteristics of river channel between Tagish and Marsh Lakes and possible restriction of outflows of Nares Lake at Ten Mile Point. This was deemed necessary to aid in determining the configuration for flow routing through the Bennett, Nares, Tagish and Marsh Lake system. The aim of the investigation is to determine whether the four lakes could be separated hydrologically or if in fact they should be treated as one lake as in previous work. For this purpose the surveys were designed to help in determining the stage-discharge relationships between Tagish and Marsh Lakes, Nares and Tagish Lakes and Bennett and Nares Lakes, and to confirm if the flow constrictions between the lakes are negligible.

The field surveys were conducted between August 16 to 23, 1982 along Tagish River and Nares Lake. The following data was collected:

(1) typical cross sections along Tagish River and Nares Lake,
(2) the water level at each cross section in terms of G.S.C. datum,
(3) the water levels at each of the four lakes,
(4) the discharges at the outlet of Bennett Lake and at the outlet of Tagish Lake.

The data represents typical high water information.

The survey information will be used in hydraulic calculations to determine if separate stage-discharge relationships should be developed for each of the four lakes and to formulate such relationships if they are found to be necessary.

Some observations made during the survey and the information obtained from the survey are described in the following sections. The field survey team

consisted of Messrs. M.V. Mazalek, R.N. Boak, and J.C.Y. Lee. The areas covered by the surveys are shown in Figure 1.

Measurement of the Cross-sections

The methods used in these surveys to obtain the cross-sections depend on the width, depth and location (such as a bridge) of the cross-sections.

Three methods adopted by this survey are:

(1) Tape & Weight - this method is used for the cross-sections where point measurement of the depth at any location along the cross-section is possible. This method is particularly applicable to the bridge cross-section when metering is carried out at the same time. The method was used for the cross-section at Tagish highway bridge and Carcross foot bridge.

(2) Tape & Sounder - this method places a marked cable across the river. A depth sounder on the boat is then run alongside the cable to obtain the calibrated depth from echo (Figure 2) at different marked locations of the cable. The marked locations provide the horizontal distances for the corresponding depths obtained from the sounder. This method is difficult to use in a very wide channel and at a location where the passage of boats is frequent. The method was used for some cross-sections at Tagish River taken during a weekday when boating activities along the river were minimal.

(3) Transit & Sounder - this method has been used to replace the method of tape and sounder in measuring the cross-sections at Nares Lake where the width of the cross-sections is as wide as 1000 metres. This method uses a transit on the bank to locate the various positions of a boat carrying a depth sounder and running from one bank to the other at a pre-specified cross-section. The calculation of the positions of the boat from transit readings gives the horizontal distances for the corresponding depths obtained from the sounder.

Field Survey for Tagish River

Five cross-sections were surveyed from the outlet of Tagish Lake to the highway bridge at Tagish River as shown in Figure 3. The results of the field survey are summarized below:

Cross-Section Number	Water Surface Elevation	Surface Width	Max. Depth	Method Used
	metres (ft)	metres (ft)	metres (ft)	
TX-1	656.33 (2153.31)	405.4 (1330)	4.8 (15.8)	Tape & Sounder
TX-2	656.31 (2153.24)	246.0 (807)	5.3 (17.5)	Transit & Sounder
TX-3	656.22 (2152.94)	393.8 (1292)	4.7 (15.5)	Tape & Sounder
TX-4	656.20 (2152.88)	339.3 (1113)	4.1 (13.1)	Tape & Sounder
TX-5	656.14 (2152.70)	336.8 (1105)	6.0 (19.6)	Tape & Weight

In addition, the discharge was measured on August 17 at cross-section TX-5 (highway bridge at Tagish River). The discharge measured at the time was 490 cubic metres per second which represents the flow occurring during the measurement of the above cross-sections.

There is a G.S.C. bench mark located near the highway between cross-sections TX-3 and TX-4. In addition, there are highway bench marks along the Tagish-Carcross Road and a bench mark of the Topographic Survey of Canada at the west end of the Tagish River bridge. Levelling was done from G.S.C. datum to nearby highway bench marks for verification and it was found that the bench marks and the datum were in agreement. Based on this finding, the water surface elevations for the cross-sections TX-1 and TX-2 were levelled from the highway bench mark T76. The water surface elevations for the cross-sections TX-3, TX-4 and TX-5 were levelled from G.S.C. datum. The results given in the table show that the difference of water surface elevations between cross-sections TX-1 and TX-5 is only 0.19 metres. It is expected that the difference would be greater during the low water season.

It was noted during the survey that the left bank of the Tagish River was mainly formed by sandy soil and appeared very unstable as the erosion process has not ceased. This is evident by the fact that the trees have lost their bases and have fallen by the bank due to erosion. Immediately upstream of cross-section TX-4, there is an eroding bluff up to 15 metres high. The trees along the top edge of the bluff are supported only by part of their roots into loose sandy soil (Figure 4) and are expected to fall within a short time.

There is a marsh area immediately downstream of cross-section TX-1. Part of this area was flooded brush land. The levelling work in this area was difficult as vision was restricted by the bushes.

Cross-section TX-3 did not go through the middle part of the island because of a private home located there. Instead, the cross-section was taken at the downstream end of the island. This cross-section is considered to be valid for the island section of the river as the island is relatively small.

Field Survey for Nares Lake

Five cross-sections were surveyed from the outlet of Bennett Lake to the outlet of Nares Lake including Ten Mile Point as shown in Figure 5. The results of the field survey are summarized below:

Cross-Section Number	Water Surface Elevation metres (ft)	Surface Width metres (ft)	Max. Depth metres (ft)	Method Used
NX-1	656.37(2153.46)	100.0 (328)	4.8(15.6)	Tape & Weight
NX-2	656.37(2153.45)	1318.0(3970)	3.2(11.5)	Transit & Sounder
NX-3	656.37(2153.45)	1001.9(3287)	29.1(95.5)	Transit & Sounder
NX-4	656.36(2153.40)	484.6(1950)	13.4(44.0)	Tape & Sounder
NX-5	656.34(2153.35)	727.9(2388)	21.2(69.5)	Transit & Sounder

In addition, the discharge was measured on August 16 at the cross-section NX-1 (foot bridge at Carcross). The discharge measured at the time was

80 cubic metres per second which represents the flow in effect during the survey.

There is a GSC bench mark at the south end of the Carcross Railway Station. There are also bench marks along the highway between Carcross and Skagway. Levelling was carried out from this GSC datum to the highway bench mark near cross-section NX-2 for verification. It was found that the GSC datum was 0.155 metres lower than the highway bench mark and GSC office in Whitehorse has been advised of this discrepancy. It was noted that the GSC bench marks had been installed in 1948 and have not been re-surveyed since that time. If the surface water elevations for Nares Lake were computed based on the GSC datum at Carcross, the surface water elevation at the downstream end of Tagish Lake (cross-section TX-1) would have been higher than the upstream end at cross-section NX-5. This anomalous phenomenon was eliminated by applying the highway bench marks to the computation of water surface elevations for Nares Lake, as shown in the table above, providing virtually a constant level for Tagish Lake.

It was noted that Ten Mile Point looked completely different from what is shown on topographic maps. The supposed peninsula was mostly under the water and looked like a small island covered with bushes in the middle of the lake (Figure 6). The water running through the middle part of Ten Mile Point had a depth of about 0.61 metres and a width of about 30 metres (Figure 7). In addition, the difference in water levels between Nares and Tagish Lakes was so small (compare water levels of NX-3 and NX-5) that both lakes indeed appear to be one lake. From this survey and observation it is concluded that Ten Mile Point does not act as a control or restriction of the Nares Lake outflow during high water season.

General Discussion

The WSC gauging stations above the Yukon River at Whitehorse are given in Table 1. The datum at "Bennett Lake at Carcross" has been based on the GSC datum near Carcross Railway Station. It is understood that the WSC gauge

at Bennett Lake has not been relocated or re-surveyed since 1954. A comparison of the water surface elevations of Bennett and Marsh Lakes as published by Water Survey of Canada indicates that the water surface elevations at Marsh Lake were higher than those of Bennett Lake during the winter and spring of 1980 (refer to Table 2) while the records of 1954 and 1955 did not show this trend clearly (Table 3). This discovery has been based only on a few samples and it is believed that more investigations will be required in order to clear up this anomalous phenomenon.

It was noted that the water levels during the period of the field surveys were reasonably stable and that the results obtained over a span of several days were uniform and comparable. For the purpose of this study, the results obtained from the field surveys were adjusted and based on the highway bench marks so that a comparison could be made on a common basis between the results of the Nares Lake and the Tagish River surveys. The fact that there was only a negligible difference of 0.01 metres between the water surface elevations at cross-sections NX-5 and TX-1 of the Tagish Lake further indicates that the results of the field surveys of Nares Lake and Tagish River are comparable if all the levels are related to the Tagish Lake level.

For the hydrologic routing study, it was questioned whether Bennett, Nares, Tagish and Marsh Lakes should be treated as four lakes or be treated as one lake hydrologically. The results of the field surveys show that there was only a difference of 0.04 metres between the water surface elevations at Bennett Lake and Tagish Lake (compare cross-sections NX-1 and TX-1). From the results of this comparison, it appears that Bennett, Nares and Tagish Lakes in fact act as one lake under backwater control from Marsh Lake.

From observations at Ten Mile Point it appears that Tagish and Nares Lakes act as one lake at all seasons. Further investigations at low water levels may be necessary to determine if Bennett and Tagish Lakes act as one lake at low water levels.

Table 1: WSC Stations above Yukon River at Whitehorse

Station No.	Station Name	Type	Record Period*
09AA001	Atlin L. at Atlin	Stage	July/50-Dec./81
09AA003	Lindeman Cr. near Bennett	Stage	July/50-Dec./81
09AA004	Bennett L. at Carcross	Stage	July/47-Dec./81
09AA006	Atlin R. near Atlin	Discharge	July/50-Dec./81
09AA007	Lubbock R. near Atlin	Discharge	Oct/54-Dec./81
09AA008	Pine Cr. near Atlin	Discharge	July/55-Oct/70
09AA009	Watson R. near Carcross	Discharge	Feb./55-Dec./73
09AA010	Lindeman Cr. near Bennett	Discharge	Oct./54-Dec./81
09AA011	Tagish Cr. near Carcross	Discharge	Aug./55-May/71
09AA012	Wheaton R. near Carcross	Discharge	Mar./56-Dec./81
09AA013	Tutshi R. at outlet of Tushi R.	Discharge	July/56-Dec./81
09AA014	Fantail R. at outlet of Fantail R.	Discharge	Oct./56-Dec./81
09AA015	Wann R. near Atlin	Discharge	Oct./58-Dec./81
09AA016	Fantail L. near Atlin	Stage	Oct./56-Dec./81
09AB001	Yukon R. at Whitehorse	Discharge	Oct./43-Dec./81
09AB002	Yukon R. above Control Dam near Whitehorse	Stage	1941-57
09AB003	Yukon R. below Control Dam near Whitehorse	Discharge	1941-60
09AB004	Marsh L. near Whitehorse	Stage	May/50-Dec./81
09AB008	M'Clintock R. near Whitehorse	Discharge	Oct./55-Dec./81

* Including incompleted records

Table 2. Comparison of 1980 Surface Water Elevations

Date	Bennett Lake (metres)	Marsh Lake (metres)	Bennett-Marsh (metres)
Jan. 1	655.969	656.091	-0.122
Feb. 1	655.740	655.852	-0.112
Mar. 1	655.383	655.523	-0.140
Apr. 1	654.911	654.955	-0.044
May 1	654.781	654.319	-0.052
June 1	654.917	654.312	0.605
July 1	655.837	655.626	0.211
Aug. 1	656.403	656.197	0.206
October 1	655.958	656.161	-0.203
November 4	656.011	656.015	-0.004
December 1	655.813	655.928	-0.115

Table 3. Comparison of 1954-55 Surface Water Elevations

Date	Bennett Lake	Marsh Lake	Bennett-Marsh
	metres (feet)	metres (feet)	metres (feet)
Oct. 1/54	655.674 (2151.16)	655.195 (2149.59)	0.479 (1.57)
Nov. 1/54	655.064 (2149.16)	654.912 (2148.66)	0.152 (0.50)
Nov. 27/54	654.960 (2148.82)	654.960 (2148.82)	0 (0)
Feb. 7/55	654.860 (2148.49)	654.820 (2148.36)	0.040 (0.13)
Mar. 14/55	654.683 (2147.91)	654.683 (2147.91)	0 (0)
Apr. 7/55	654.601 (2147.64)	654.604 (2147.65)	-0.003(-0.01)
May 2/55	654.531 (2147.41)	654.568 (2147.53)	-0.037(-0.12)
June 16/55	654.784 (2148.24)	654.774 (2148.21)	0.010 (0.03)
July 1/55	655.469 (2150.49)	655.155 (2149.46)	0.314 (1.03)
Aug. 1/55	656.244 (2153.03)	656.015 (2152.28)	0.229 (0.75)
Sept. 1/55	655.826 (2151.66)	655.606 (2150.94)	0.220 (0.72)
Sept. 30/55	655.393 (2150.24)	655.119 (2149.34)	0.274 (0.90)

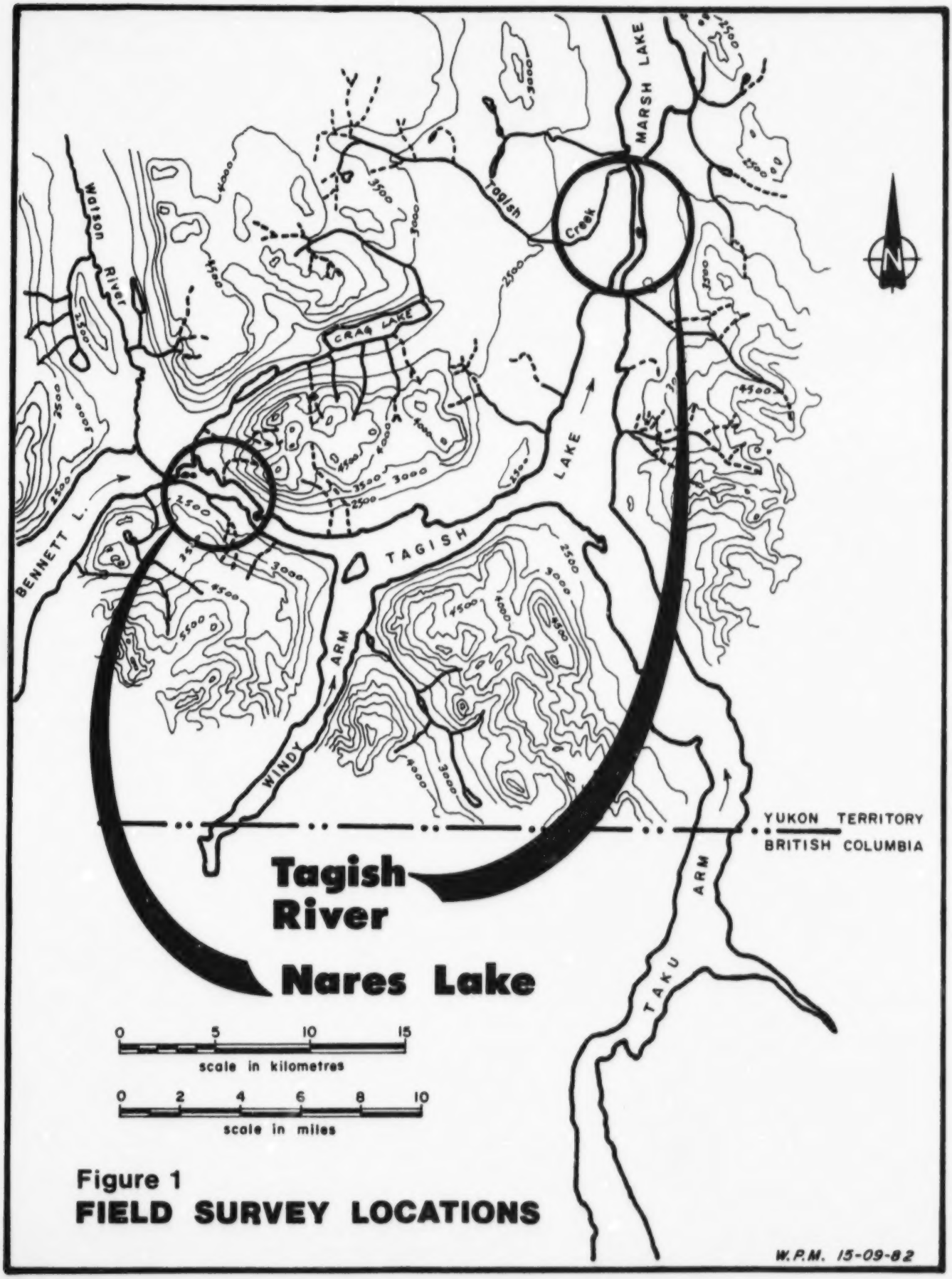


Figure 1
FIELD SURVEY LOCATIONS

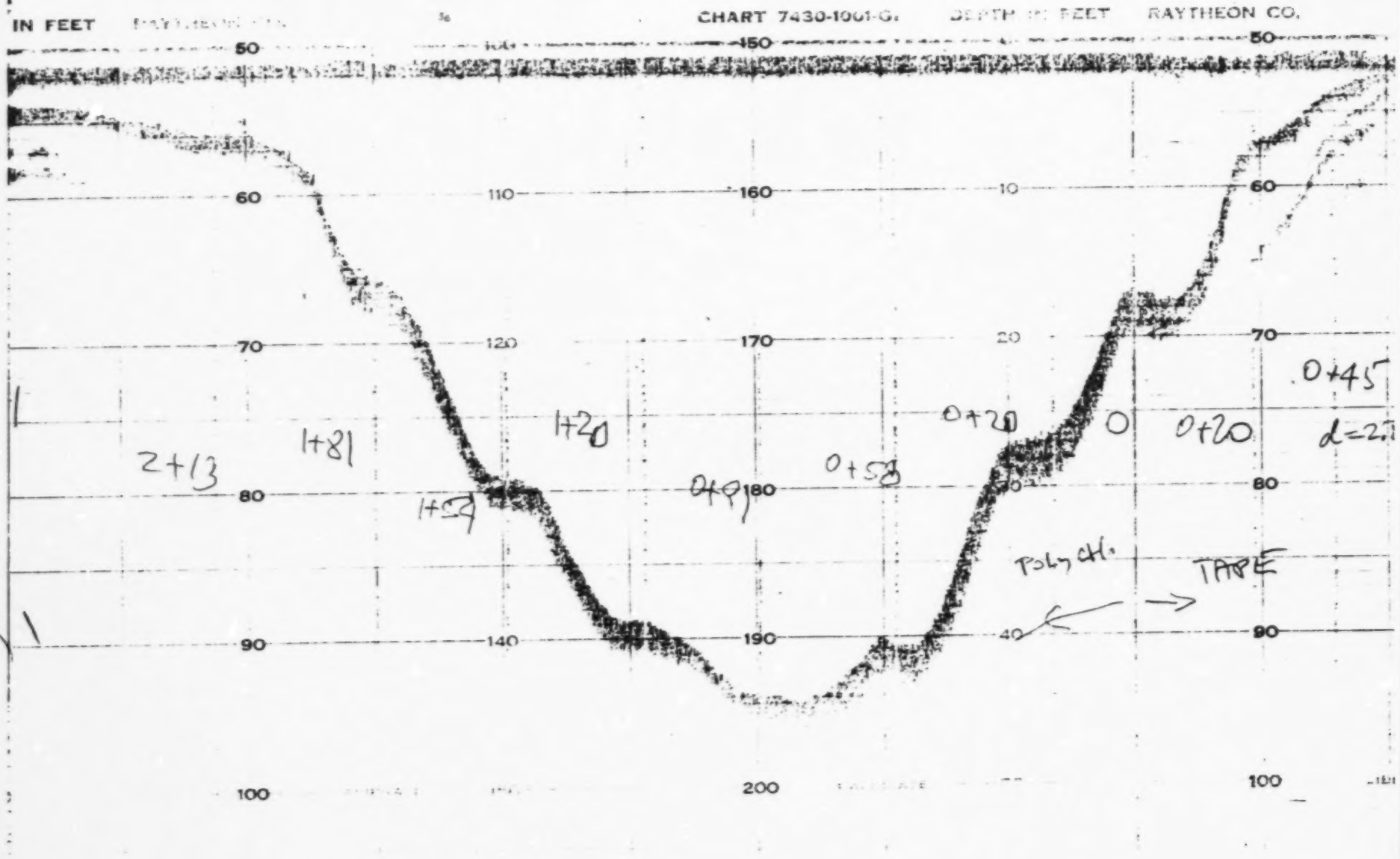


Figure 2 - Sample Chart of a Depth Sounder

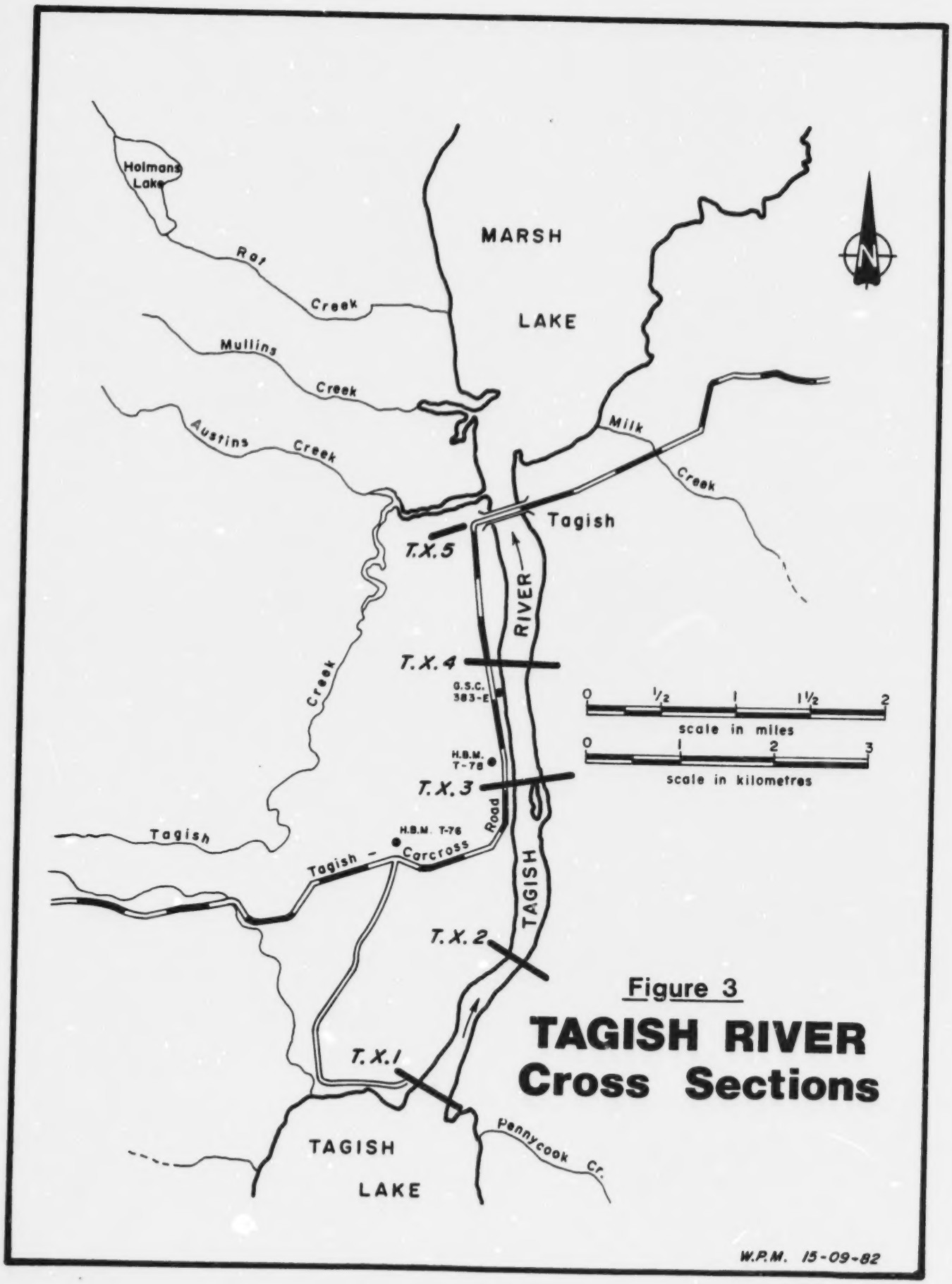


Figure 3

TAGISH RIVER Cross Sections

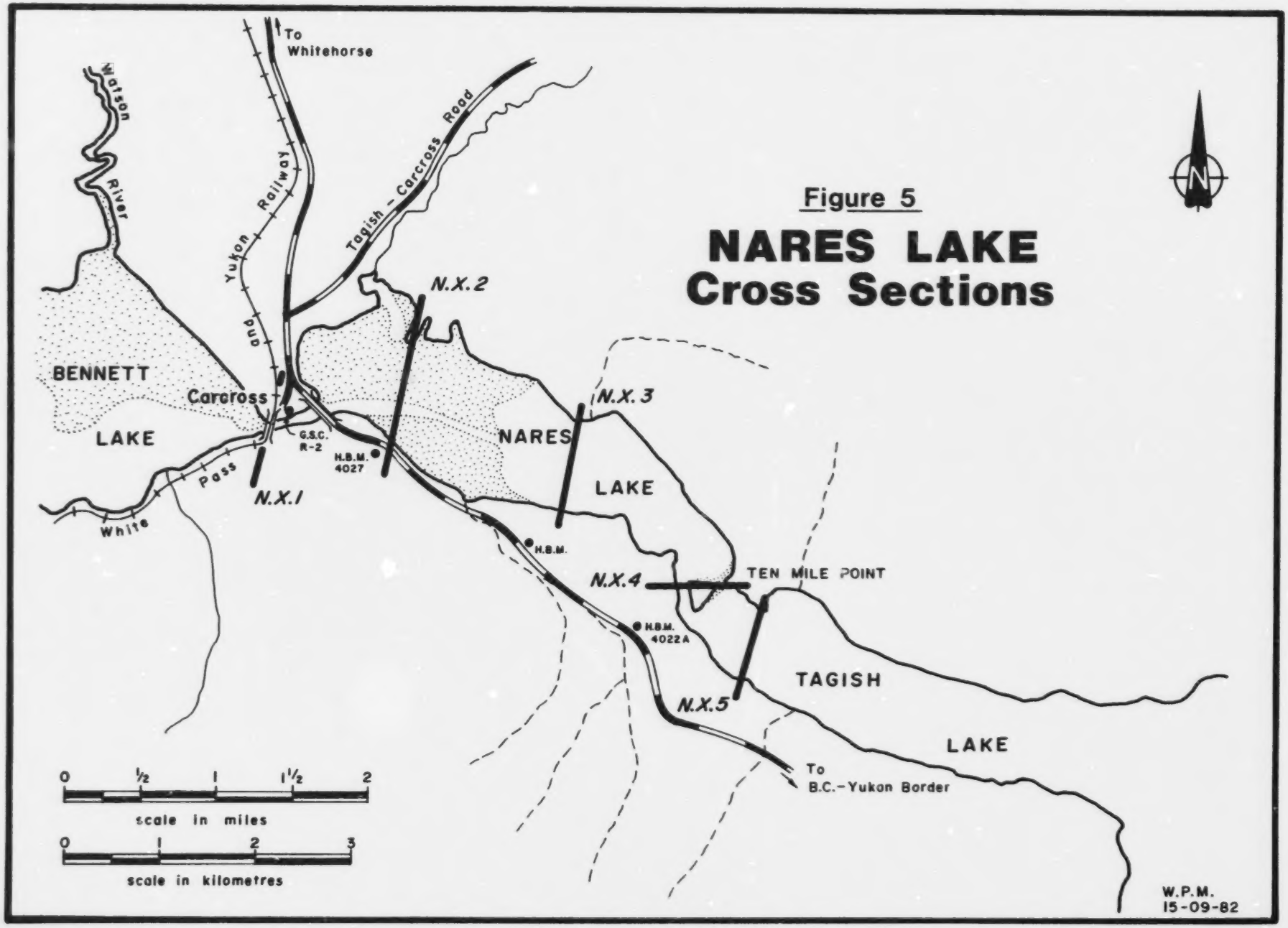


Figure 5
NARES LAKE
Cross Sections
To Whitehorse
Watson River
Yukon Railway
Tagish - Carcross Road
N.X.2
N.X.3
N.X.4
N.X.5
N.X.1
BENNETT LAKE
Carcross
G.S.C. R-2
H.B.M. 4027
NARES LAKE
H.B.M.
H.B.M. 4022A
TEN MILE POINT
TAGISH LAKE
White Pass
To B.C.-Yukon Border
0 ½ 1 1½ 2
scale in miles
0 1 2 3
scale in kilometres
W.P.M.
15-09-82

FIGURE 4
SEVERE EROSION
TAGISH RIVER LEFT BANK

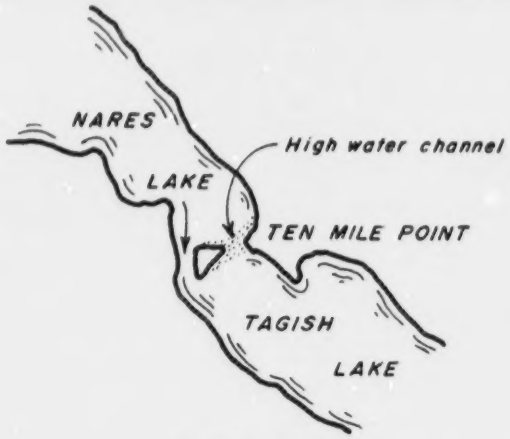


FIGURE 6
HIGH WATER
TEN MILE POINT – NARES LAKE

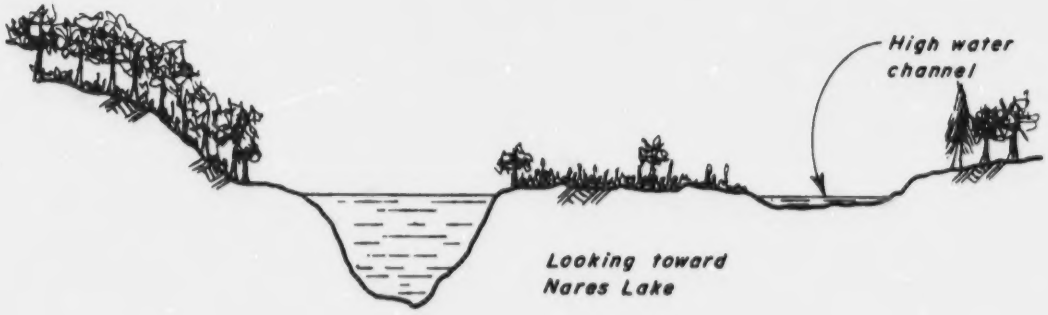


FIGURE 7
HIGH WATER
TEN MILE POINT – NARES LAKE

ATTACHMENTS

Photographs, Tabulations, and Plots
of the Cross-Sections

Upper Nares Lake looking from highway bridge at Carcross (Aug/82)
(looking downstream towards cross-section NX-2)

Cross-section TX-2 looking upstream (Aug/82)

Note: Additional photographs showing the survey area and the cross-sections are available from the authors.

TABULATION OF CROSS-SECTION NX-1

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	656.375	0	Water Level, Left Bank
0 + 06.0	654.98	1.39	
0 + 12.2	654.04	2.33	
0 + 19.8	652.12	4.25	
0 + 26.2	652.06	4.31	
0 + 30.5	652.06	4.31	
0 + 37.5	651.94	4.43	
0 + 42.7	651.63	4.74	
0 + 48.8	651.85	4.52	
0 + 55.5	652.42	3.95	
0 + 61.0	653.19	3.18	
0 + 67.1	654.38	1.99	
0 + 73.5	654.65	1.72	
0 + 79.2	654.80	1.57	
0 + 85.3	655.08	1.29	
0 + 91.4	655.62	0.75	
1 + 00.0	656.375	0	Water Level, Right Bank

TABULATION OF CROSS-SECTION NX-2

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	657.91	-	Left Bank
0 + 07.6	657.58	-	
0 + 20.7	657.12	-	
0 + 31.7	656.37	0	Water Level
0 + 40.8	655.59	0.78	
0 + 52.7	655.32	1.05	
0 + 80.0	654.98	1.39	
1 + 03.6	654.80	1.57	
1 + 71.3	654.77	1.60	
1 + 82.9	654.98	1.39	
2 + 11.8	654.80	1.57	
2 + 22.5	655.02	1.35	
2 + 49.0	654.50	1.87	
2 + 57.6	654.98	1.39	
2 + 74.3	654.50	1.87	
2 + 85.9	654.80	1.57	
2 + 98.7	654.92	1.45	
3 + 19.1	654.80	1.57	
3 + 34.1	655.11	1.26	
4 + 21.2	655.14	1.23	
4 + 75.5	655.41	0.96	
5 + 02.9	655.66	0.71	
5 + 21.2	655.44	0.93	
5 + 77.6	655.47	0.90	
5 + 89.8	655.72	0.65	
6 + 01.4	655.41	0.96	
6 + 90.1	655.53	0.84	
7 + 67.2	655.41	0.96	
8 + 19.9	655.35	1.02	
8 + 53.4	653.77	2.60	
8 + 78.1	654.47	1.90	
8 + 97.0	654.28	2.09	
9 + 42.1	653.19	3.18	
9 + 86.6	654.44	1.93	
9 + 99.7	654.86	1.51	
10 + 18.0	655.05	1.32	
10 + 60.1	654.68	1.69	
11 + 07.6	655.29	1.08	
12 + 17.1	655.35	1.02	
12 + 61.0	655.35	1.02	
12 + 85.6	654.50	1.87	
13 + 18.3	654.50	1.87	
13 + 43.6	655.99	0.38	
13 + 49.7	656.37	0	Water Level
13 + 55.4	656.57	-	
13 + 62.2	657.70	-	
13 + 67.6	657.03	-	
13 + 78.3	657.27	-	
13 + 80.1	658.52	-	Right Bank

TABULATION OF CROSS-SECTION NX-3

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	658.22	-	Left Bank
0 + 09.8	657.36	-	
0 + 20.4	657.12	-	
0 + 25.0	657.09	-	
0 + 30.2	656.60	-	
0 + 39.0	656.37	0	Water Level
0 + 41.1	655.93	0.44	
0 + 47.2	653.95	2.42	
0 + 49.7	639.32	17.05	
0 + 70.4	633.22	23.15	
0 + 83.8	628.65	27.72	
0 + 94.8	627.58	28.79	
1 + 16.1	627.28	29.09	
1 + 32.6	629.56	26.81	
1 + 46.3	632.00	24.37	
1 + 54.8	632.46	23.91	
1 + 63.4	632.31	24.06	
1 + 79.8	629.41	26.96	
1 + 92.3	628.95	27.42	
2 + 35.3	635.36	21.01	
2 + 53.6	632.92	23.45	
2 + 68.5	633.22	23.15	
2 + 89.6	633.37	23.00	
3 + 13.3	636.27	20.10	
3 + 30.7	640.99	15.38	
3 + 57.5	643.58	12.79	
3 + 72.8	643.80	12.57	
4 + 20.0	643.34	13.03	
4 + 81.6	643.89	12.48	
6 + 01.7	647.40	8.97	
8 + 09.2	648.46	7.91	
8 + 96.4	649.22	7.15	
9 + 17.4	649.68	6.69	
9 + 39.7	650.29	6.08	
9 + 62.2	651.51	4.86	
9 + 76.9	653.79	2.58	
9 + 99.1	654.16	2.21	
10 + 10.1	654.41	1.96	
10 + 38.5	655.78	0.59	
10 + 40.9	656.37	0	Water Level
10 + 52.5	657.76	-	
10 + 58.9	658.95	-	Right Bank

TABULATION OF CROSS-SECTION NX-4

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	659.58	-	Left Bank
0 + 04.9	656.36	0	Water Level
0 + 07.9	655.75	0.61	
0 + 71.9	655.69	0.68	
1 + 02.1	656.05	0.31	
1 + 30.5	656.26	0.10	
1 + 77.1	656.51	-	
2 + 09.1	656.26	0.10	Ten-Mile Point
2 + 33.5	656.51	-	
2 + 59.4	656.94	-	
2 + 76.1	657.08	-	
3 + 82.8	656.05	0.31	
3 + 95.0	655.41	0.95	
4 + 05.7	654.74	1.62	
4 + 09.7	653.83	2.53	
4 + 13.3	651.78	4.58	
4 + 20.3	647.74	0.40	
4 + 23.7	647.58	8.78	
4 + 29.5	644.77	11.60	
4 + 40.7	642.95	13.41	
4 + 45.0	643.16	13.20	
4 + 49.6	644.38	11.98	
4 + 52.0	644.16	12.20	
4 + 59.0	648.34	8.02	
4 + 62.4	648.49	7.87	
4 + 68.5	651.38	4.98	
4 + 70.6	651.21	5.15	
4 + 74.6	654.44	1.92	
4 + 82.2	655.50	0.86	
4 + 89.5	656.36	0	Water Level
4 + 94.4	657.44	-	
5 + 00.2	657.55	-	
5 + 18.8	659.10	-	Right Bank

TABULATION OF CROSS-SECTION NX-5

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	658.22	-	Left Bank
0 + 01.5	656.34	0	Water Level
0 + 03.0	655.90	0.44	
0 + 08.5	654.53	1.81	
0 + 17.1	653.92	2.42	
0 + 50.3	653.46	2.88	
1 + 07.8	650.35	6.01	
1 + 75.6	648.74	7.60	
2 + 49.0	647.36	8.98	
3 + 00.5	646.45	9.89	
3 + 23.4	644.32	12.02	
3 + 50.8	640.81	15.53	
3 + 84.0	638.37	17.97	
3 + 98.1	638.59	17.75	
4 + 23.7	639.59	16.75	
4 + 31.3	640.20	16.14	
4 + 38.9	640.20	16.14	
4 + 67.9	635.33	21.01	
4 + 85.9	635.26	21.08	
4 + 95.3	635.17	21.17	
5 + 13.3	636.09	20.25	
5 + 37.9	639.59	16.75	
5 + 64.2	644.32	12.02	
5 + 85.5	646.60	9.74	
6 + 09.0	647.88	8.46	
6 + 45.6	649.50	6.84	
6 + 61.1	650.63	5.71	
6 + 69.0	651.48	4.86	
6 + 79.7	653.77	2.57	
6 + 99.5	654.28	2.06	
7 + 17.8	655.23	1.11	
7 + 21.8	655.69	0.65	
7 + 29.4	656.34	0	Water Level
7 + 35.5	656.87	-	
7 + 41.3	658.55	-	Right Bank

TABULATION OF CROSS-SECTION TX-1

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	658.22	-	Left Bank
0 + 01.2	657.21	-	
0 + 13.7	656.33	0	Water Level
0 + 29.0	655.62	0.71	
0 + 67.1	655.02	1.31	
0 + 82.3	654.56	1.77	
0 + 97.5	654.34	1.99	
1 + 12.8	654.80	1.53	
1 + 25.0	654.31	2.02	
1 + 43.3	654.44	1.89	
1 + 50.9	654.41	1.92	
1 + 81.4	653.28	3.05	
1 + 99.6	652.82	3.51	
2 + 04.2	652.82	3.51	
2 + 11.8	652.52	3.81	
2 + 14.9	653.13	3.20	
2 + 19.5	653.13	3.20	
2 + 25.5	652.64	3.69	
2 + 31.6	652.36	3.97	
2 + 34.7	652.45	3.88	
2 + 42.3	652.52	3.81	
2 + 45.4	652.30	4.03	
2 + 49.9	652.36	3.97	
2 + 54.5	652.33	4.00	
2 + 57.6	652.61	3.72	
2 + 62.1	652.06	4.27	
2 + 65.2	652.36	3.97	
2 + 80.4	652.67	3.66	
2 + 83.5	652.50	3.83	
2 + 86.5	652.52	3.81	
2 + 95.7	651.51	4.82	
3 + 03.3	652.55	3.78	
3 + 21.6	651.39	4.94	
3 + 33.8	652.36	3.97	
3 + 36.8	652.30	4.03	
3 + 41.4	652.42	3.91	
3 + 56.6	651.72	4.61	
3 + 64.2	653.89	2.44	
3 + 79.5	654.56	1.77	
3 + 94.7	654.80	1.53	
4 + 03.3	655.29	1.04	
4 + 17.6	655.96	0.37	
4 + 19.1	656.33	0	Water Level
4 + 28.2	657.55	-	
4 + 36.5	657.36	-	
4 + 45.6	657.67	-	Right Bank

TABULATION OF CROSS-SECTION TX-2

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	658.95	-	Left Bank
0 + 00.3	657.24	-	
0 + 04.0	656.30	0	Water Level
0 + 07.6	655.93	0.37	
0 + 29.3	654.16	2.14	
0 + 58.2	653.25	3.05	
0 + 67.7	652.97	3.33	
0 + 75.3	652.94	3.36	
0 + 85.3	653.25	3.05	
1 + 03.9	652.39	3.91	
1 + 06.7	652.88	3.42	
1 + 40.2	652.67	3.63	
1 + 66.1	650.96	5.34	
1 + 76.8	652.85	3.45	
1 + 82.9	652.64	3.66	
1 + 84.4	652.97	3.33	
2 + 04.2	652.94	3.36	
2 + 04.8	653.80	2.50	
2 + 10.3	654.34	1.96	
2 + 14.9	653.92	2.38	
2 + 20.4	654.83	1.47	
2 + 25.6	654.83	1.47	
2 + 31.6	654.47	1.83	
2 + 38.4	654.74	1.56	
2 + 47.5	655.47	0.83	
2 + 49.9	656.30	0	Water Level
2 + 50.9	657.00	-	
2 + 51.5	656.97	-	
2 + 52.1	658.49	-	Right Bank

TABULATION OF CROSS-SECTION TX-3

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	661.062	-	Left Bank
0 + 03.7	659.80	-	
0 + 04.6	659.40	-	
0 + 05.5	657.91	-	
0 + 08.5	656.22	0	Water Level
0 + 15.2	655.26	0.96	
0 + 24.4	654.10	2.12	
0 + 26.5	654.41	1.81	
0 + 30.5	654.10	2.12	
0 + 33.5	654.71	1.51	
0 + 37.5	654.10	2.12	
0 + 38.1	654.53	1.69	
0 + 42.7	652.42	3.80	
0 + 57.9	652.58	3.64	
0 + 67.1	652.42	3.80	
0 + 73.2	652.58	3.64	
0 + 76.2	652.42	3.80	
0 + 91.4	652.27	3.95	
0 + 97.5	652.33	3.89	
1 + 21.9	652.00	4.22	
1 + 29.5	651.94	4.28	
1 + 37.2	651.69	4.53	
1 + 44.8	651.69	4.53	
1 + 46.3	651.91	4.31	
1 + 52.4	651.91	4.31	
1 + 60.0	651.94	4.28	
1 + 67.6	651.60	4.62	
1 + 82.9	651.69	4.53	
1 + 85.9	652.33	3.89	
1 + 88.4	652.33	3.89	
1 + 89.9	653.31	2.91	
1 + 99.6	654.41	1.81	
2 + 02.1	653.80	2.42	
2 + 04.2	654.28	1.94	
2 + 10.3	654.53	1.69	
2 + 21.0	654.68	1.54	
2 + 31.6	654.83	1.39	
2 + 33.2	655.05	1.17	
2 + 36.2	655.62	0.60	

TABULATION OF CROSS-SECTION TX-3 (continued)

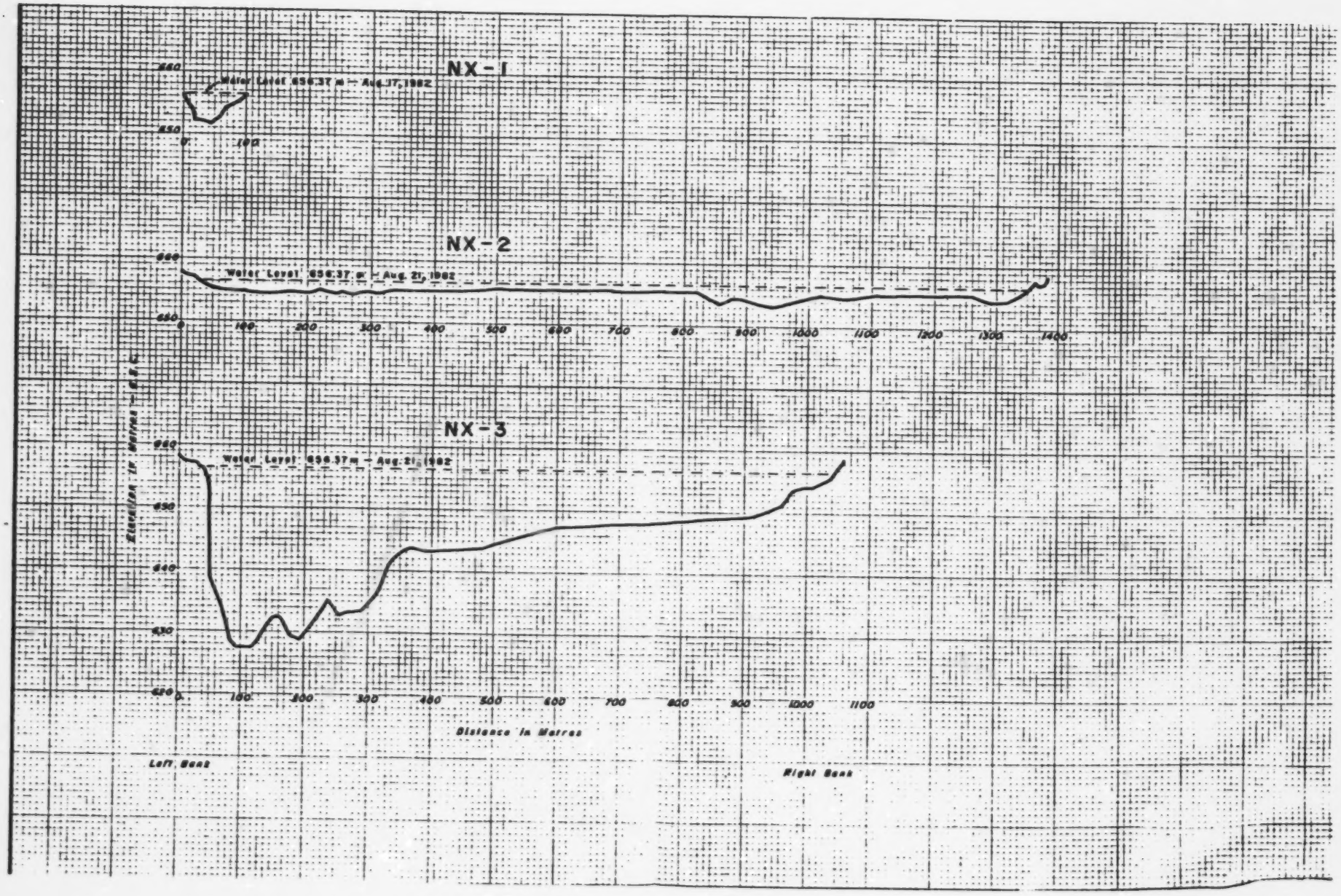
Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
2 + 43.8	655.75	0.47	
2 + 62.1	656.22	0	Water Level
2 + 66.7	657.12	-	)
2 + 68.2	657.76	-	)
2 + 73.1	658.00	-	) Island
2 + 75.2	656.75	-	)
2 + 77.1	656.22	0	Water Level
2 + 85.0	655.56	0.66	
2 + 89.6	655.50	0.72	
2 + 92.6	655.32	0.90	
2 + 95.7	655.44	0.78	
2 + 98.7	655.32	0.90	
3 + 04.8	655.32	0.90	
3 + 13.9	655.62	0.60	
3 + 15.5	654.70	1.52	
3 + 17.0	654.89	1.33	
3 + 20.0	654.98	1.24	
3 + 24.6	654.68	1.54	
3 + 35.3	653.80	2.42	
3 + 45.9	653.49	2.73	
3 + 59.7	654.22	2.00	
3 + 60.3	654.98	1.24	
3 + 67.3	653.80	2.42	
3 + 68.8	654.10	2.12	
3 + 76.4	654.41	1.81	
3 + 84.0	654.89	1.33	
3 + 91.7	655.26	0.96	
4 + 02.3	656.22	0	Water Level
4 + 21.2	659.22	-	
4 + 31.6	660.01	-	Right Bank

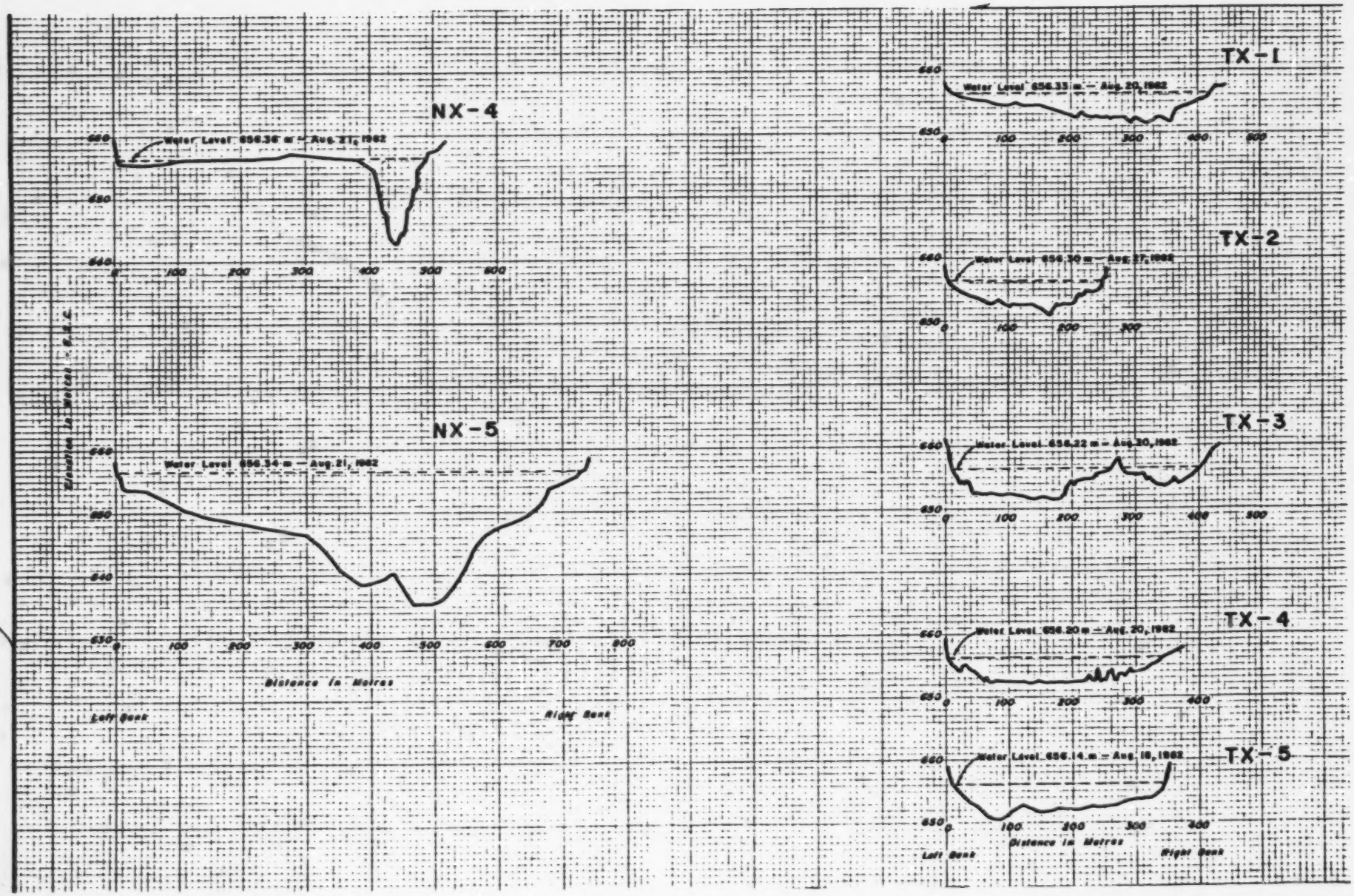
TABULATION OF CROSS-SECTION TX-4

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 00.0	659.54	-	Left Bank
0 + 02.1	656.20	0	Water Level
0 + 05.2	655.75	0.45	
0 + 20.4	654.07	2.13	
0 + 23.2	654.98	1.22	
0 + 32.0	655.13	1.07	
0 + 36.6	654.38	1.82	
0 + 45.7	654.01	2.19	
0 + 61.9	652.55	3.65	
0 + 67.1	653.22	2.98	
0 + 70.1	652.33	3.87	
0 + 79.2	652.55	3.65	
1 + 03.6	652.30	3.90	
1 + 21.9	652.27	3.93	
1 + 31.1	652.21	3.99	
1 + 41.7	652.30	3.90	
1 + 43.3	652.55	3.65	
1 + 44.8	652.27	3.93	
1 + 52.4	652.33	3.87	
1 + 73.7	652.24	3.96	
1 + 89.0	652.24	3.96	
2 + 13.4	652.45	3.75	
2 + 21.0	652.45	3.75	
2 + 24.0	653.55	2.65	
2 + 30.1	652.45	3.75	
2 + 37.1	652.85	3.35	
2 + 39.3	654.38	1.82	
2 + 40.8	652.85	3.35	
2 + 49.0	652.91	3.29	
2 + 51.5	652.85	3.35	
2 + 56.0	653.92	2.28	
2 + 60.6	654.01	2.19	
2 + 62.1	652.70	3.50	
2 + 63.7	652.61	3.59	
2 + 69.7	652.70	3.50	
2 + 72.8	653.61	2.59	
2 + 78.9	653.61	2.59	
2 + 80.4	653.16	3.04	
2 + 83.5	653.77	2.43	
2 + 86.5	654.07	2.13	
2 + 90.2	654.38	1.82	
2 + 92.6	653.92	2.28	
3 + 04.8	654.07	2.13	
3 + 20.0	654.74	1.46	
3 + 25.2	655.05	1.15	
3 + 32.2	655.26	0.94	
3 + 41.4	656.20	0	Water Level
3 + 56.6	656.87	-	
3 + 72.8	657.76	-	
3 + 74.3	657.88	-	Right Bank

TABULATION OF CROSS-SECTION TX-5

Chainage (metres)	Bottom Elevation (metres)	Depth (metres)	Note
0 + 03.4	658.92	-	Left Bank
0 + 03.4	658.09	-	
0 + 06.4	657.00	-	
0 + 09.1	656.14	0	Water Level
0 + 30.5	653.80	2.34	
0 + 48.8	652.58	3.56	
0 + 67.1	650.96	5.18	
0 + 85.3	650.17	5.97	
1 + 03.6	651.88	4.26	
1 + 21.9	652.76	3.38	
1 + 40.2	651.88	4.26	
1 + 58.5	651.88	4.26	
1 + 76.8	652.06	4.08	
1 + 95.1	652.03	4.11	
2 + 13.4	652.18	3.96	
2 + 31.6	652.64	3.50	
2 + 49.9	652.42	3.72	
2 + 68.2	652.88	3.26	
2 + 86.5	653.31	2.83	
3 + 04.8	653.58	2.56	
3 + 23.1	653.92	2.22	
3 + 41.4	655.47	0.67	
3 + 45.9	656.14	0	Water Level
3 + 48.7	657.18	-	
3 + 51.7	658.06	-	
3 + 51.7	659.05	-	Right Bank


NX-1
Water Level 656.37 m — Aug. 17, 1982
NX-2
Water Level 656.37 m — Aug. 21, 1982
NX-3
Water Level 656.37 m — Aug. 21, 1982
Elevation in Metres — G.S.C.
Distance in Metres
Left Bank
Right Bank


NX-4
Water Level 656.36 m — Aug. 21, 1982
NX-5
Water Level 656.34 m — Aug. 21, 1982
Elevation in Meters - G.S.C.
Distance in Metres
Left Bank
Right Bank
TX-1
Water Level 656.33 m — Aug. 20, 1982
TX-2
Water Level 656.30 m — Aug. 27, 1982
TX-3
Water Level 656.22 m — Aug. 20, 1982
TX-4
Water Level 656.20 m — Aug. 20, 1982
TX-5
Water Level 656.14 m — Aug. 18, 1982
Distance in Metres
Left Bank
Right Bank

APPENDIX B

Yukon River
Daily Hydrologic Model

YUKON RIVER BASIN STUDY

Hydrology Project #44

FIELD SURVEYS FOR THE YUKON HEADWATER LAKES

May 1983

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Water Planning and Management Branch
Inland Waters Directorate
Pacific and Yukon Region
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FIELD SURVEY FOR THE YUKON HEADWATER LAKES

May 1983

Introduction

As a follow-up to the field surveys for the Yukon Headwater Lakes conducted in August 1982, a survey of water surface elevations during the low flow season was conducted on May 24 and 25, 1983. By relating the water surface elevation to the elevation of temporary bench mark established at each cross-section during the survey of August 1982, less effort was required in this survey. This eliminated the need for long levelling circuits to permanent GSC or highway bench marks.

The aim of this survey was to obtain water surface profiles and to observe channel characteristics along the Tagish River and Nares Lake during the low water season. In addition, the discharges at the outlet of Bennett Lake and at the outlet of Tagish Lake were measured during the survey. Observations made during the survey and information obtained are described in the following sections. Readers should refer to Figures 3 and 4 in Appendix A for the cross-section notations used in the following descriptions.

Field Survey for Tagish River

Five cross-sections were surveyed from the outlet of Tagish Lake to the highway bridge at Tagish River. The results of the field survey are summarized below:

Cross Section Number	Water Surface Elevation	Distance from TX-1
	metres (ft)	kilometres
TX-1	654.51 (2146.79)	0
TX-2	654.52 (2146.84)	1.7
TX-3	654.33 (2146.21)	3.6
TX-4	654.33 (2146.20)	4.9
TX-5	654.23 (2145.89)	6.5

In addition, the discharge was measured on May 25 at cross-section TX-5 (highway bridge at Tagish River) as 176 cubic metres per second. It was noted during the survey of the above cross-sections that a gusty wind was blowing in a northward direction toward the outlet of Tagish Lake which caused significant wave action especially at the cross-sections TX-1 and TX-2. As a result, it is possible that the water surface elevation obtained for these two cross-sections may be higher than would have been obtained under normal conditions due to wind set-up and wave action.

Field Survey for Nares Lake

Five cross-sections were surveyed from the outlet of Bennett Lake to the outlet of Nares Lake including Ten Mile Point. The results of the field surveys are summarized below:

Cross-Section Number	Water Surface Elevation	Distance from NX-1
	metres (ft)	kilometres
NX-1	654.71(2147.46)	0
NX-2	654.59(2147.04)	1.5
NX-3	654.47(2146.66)	3.4
NX-4	654.48(2146.70)	5.5
NX-5	654.49(2146.74)	6.4

In addition, the discharge was measured on May 24 at cross-section NX-1 (foot bridge at Carcross) as 51 cubic metres per second. The lake level was so low at this time of the year that a vast area of lake between NX-1 and NX-2 was uncovered. Only a main channel and a side channel run from NX-1 and NX-2 was visible. It was noted that at Ten Mile Point there was only a short channel connecting both Nares and Tagish Lakes and the portion of Ten Mile Point which was flooded in August 1982 was dry. It appeared that the flow in the channel was tranquil and that

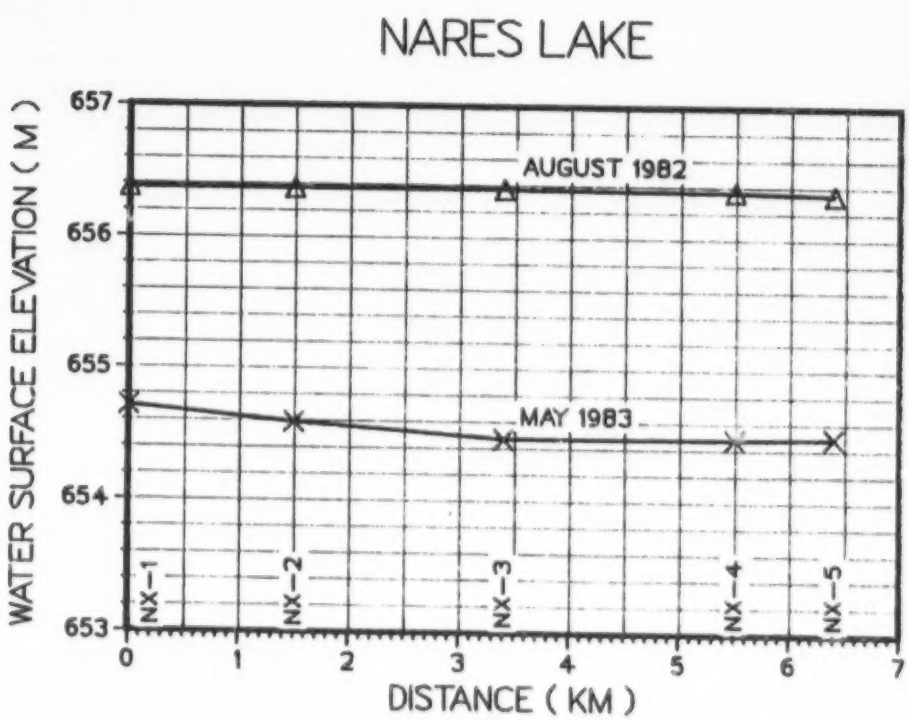
Ten Mile Point does not act as a control or restriction of the Nares Lake outflow during low water season.

General Discussion

The water surface elevations obtained from this survey were plotted for both Nares Lake and Tagish River in Figure 1. The results obtained from the previous survey of August 1982 were also plotted in the same figure for comparison purposes. It was noted that the water surface elevation at the outlet of Tagish Lake (TX-1) was slightly higher than that at the outlet of Nares Lake (NX-4). This anomalous phenomenon was probably due to the wind effect at the outlet of Tagish Lake as described in the previous section. The gusty wind blowing toward the restricted outlet of the lake tended to push up the lake level, a phenomenon known as wind set-up.

The results of this survey show that there was a difference of 0.22 metres between the water surface elevations at Bennett and Tagish Lakes in comparison to 0.03 metres shown in the surveys of August 1982 (compare cross-sections NX-1 and NX-5). Furthermore there was a difference of 0.28 metres between Tagish and Marsh Lakes compared to 0.22 metres shown in the surveys of August 1982 (reference cross-sections TX-1 and TX-5). It is believed that if the wind effect at the outlet of Tagish Lake is excluded the difference in levels of Tagish and Marsh Lakes would remain fairly constant during high and low water seasons.

The daily hydrologic flow model developed for the Yukon River Basin Study considered Bennett, Nares, Tagish and Marsh Lakes as one lake. This assumption is adequate for the present study. However, the data obtained from the surveys will be useful in further refining the relationship of the upstream lakes portion of the model.



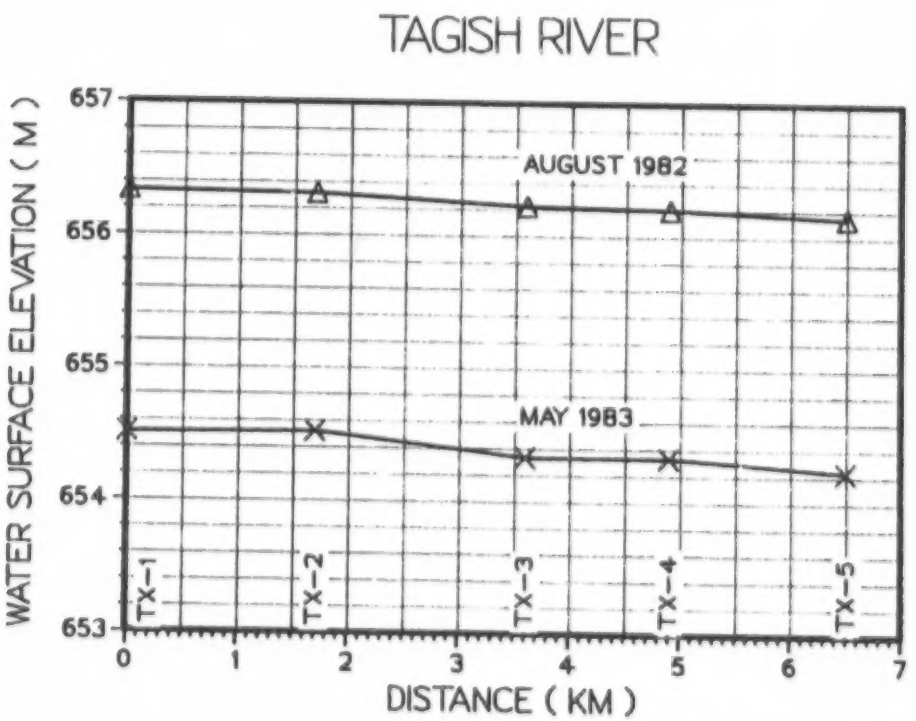
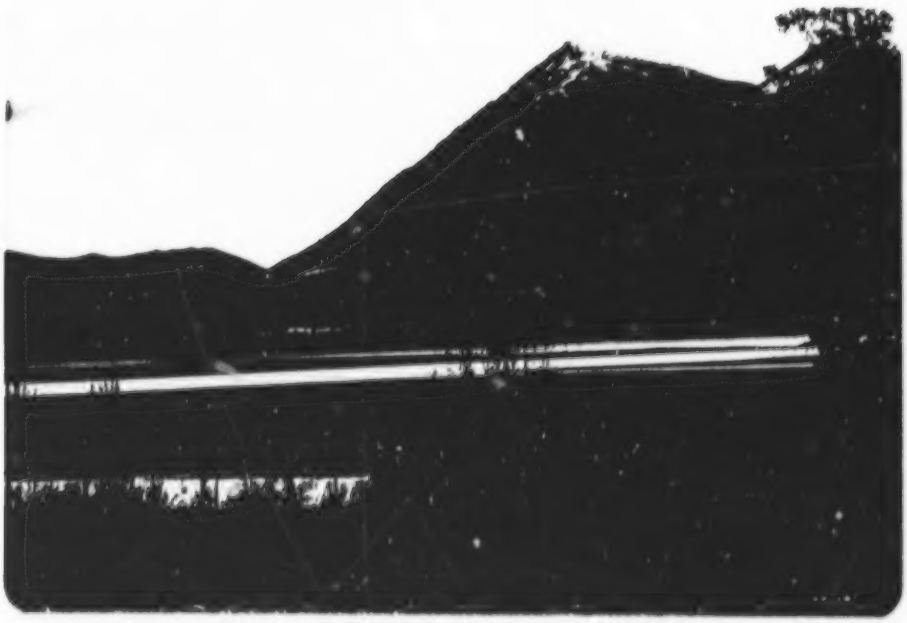


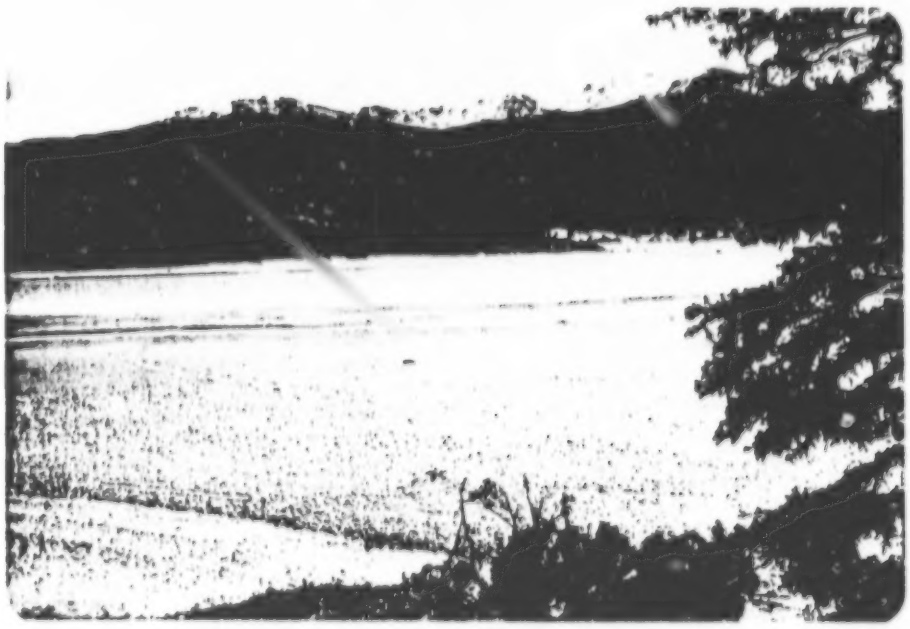
FIGURE 1: WATER SURFACE ELEVATIONS FOR NARES LAKE AND TAGISH RIVER

ATTACHMENT

Photographs of Cross-Sections



Upper Nares Lake looking north along cross-section NX-2



Tagish River looking eastward along cross-section TX-1

Note: Additional photographs showing the survey area and the cross-sections are available from the authors.